

The AMSAT[®] Journal

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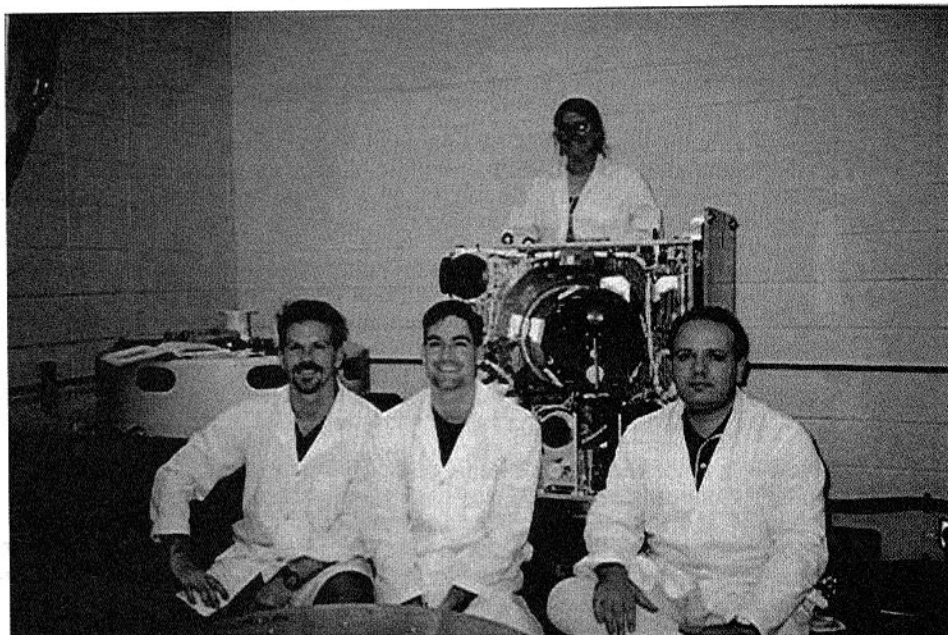
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ASUSat1 was recently integrated to the JAWSAT Multi-Payload at Weber State University. From left to right are ASUSat1 team members: Richard Nielson, Brian Underhill, Dr. Helen Reed, Assi Friedman, 4X1KXX/KK7KX. (ASU photo)

JAWSAT, ASUSat1, OPAL, and StenSat Ready for Launch

On 15 October 1999, four Amateur Radio satellites will be launched into orbit from Vandenberg Air Force Base, California. An Air Force Orbital Suborbital Program (OSP) launcher, will place these Amateur Radio satellites into a 750 km by 100° inclination and near-sun synchronous orbit. Each satellite has been recently integrated to the Joint Air Force Academy and Weber State Satellite (JAWSAT) Multi-Payload Adapter (MPA). While still attached to the final stage, each satellite will be released at separate times with JAWSAT recording the event via a video camera. This article provides an overview of each of these Amateur Radio satellites.

[continued on page 4]

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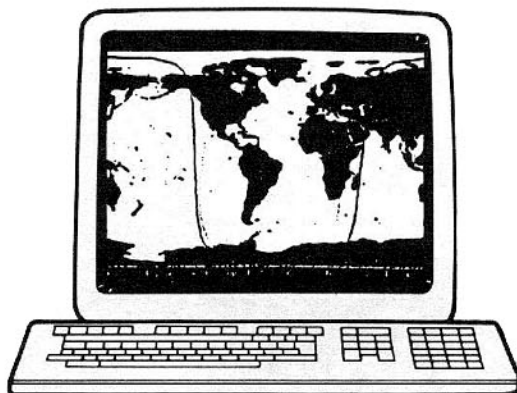
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The **Kansas City Tracker** is a hardware and software package that connects between your rotor controller and an IBM XT, AT, or clone. It controls your antenna array, letting your PC track any satellite or orbital body. The **Kansas City Tracker** hardware consists of a half-size interface card that plugs into your PC. It can be connected directly to Kenpro 5400A/5600A or Yaesu G5400B/G5600B rotor controllers. It can be connected to other rotor assemblies using our Rotor Interface Option.

The **Kansas City Tuner** Option provides automatic doppler-shift compensation for digital satellite work. The **Tuner** is compatible with most rigs including Yaesu, Kenwood, and ICOM. It controls your radio thru the radio's serial computer port (if present) or through the radio's up/down mic-click interface. The **Kansas City Tuner** Option is perfect for low-orbit digital satellites like the NOAA and Microstat satellites.

The **Kansas City Tracker** and **Tuner** include custom serial interfaces and do not use your computer's valuable COMM ports. The software runs in your PC's "spare time," letting you run other programs at the same time.

The **Kansas City Tracker** and **Tuner** programs are "Terminate-and-Stay-Resident" programs that attach themselves to DOS and disappear. You can run other DOS programs while your antenna tracks its target and your radios are tuned under computer control. This unique feature is especially useful for digital satellite work; a communications program like PROCOMM can be run while the PC aims your antennas and tunes your radios in its spare time. Status pop-up windows allow the user to review and change current and upcoming radio and antenna parameters. The KC Tracker is compatible with DOS 2.00 or higher.

Satellite and EME Work

The **Kansas City Tracker** and **Kansas City Tuner** are fully compatible with N4HY's QUIKTRAK and with Silicon Solution's GRAFTRAK. These programs can be used to load the **Kansas City Tracker's** tables with more than 50 satellite passes.

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AMSAT-NA can take your order for a Kansas City Tracker/Tuner or one of many Satellite Tracking software packages that support the KCT, such as Quiktrak, Graftrak, and WiSP for Windows. When you order thru them, they receive a Donation in your name towards the Phase 3D Project. Their telephone number is 301-589-6062.



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Apogee View

Leaving a Legacy

Those of you who live and work in product organizations know that such organizations run on three basic input ingredients. In simple terms, those ingredients are: people, money and things. The money is used by the people in the organization to purchase and then add value to raw materials or other tangible (or intangible) things so as to produce whatever it is that the organization is set up to produce.

AMSAT, even though it is a non-profit corporation, is no different. While our product line may be a bit more nebulous than that of a corporation established solely to produce a physical thing for profit, the basic resource equation is just as true for us as it is for any other organization. We combine the input of our people's skills, abilities and talents along with donated resources (your generous donations of time and money) to produce output. In our case, that "output" includes physical satellite systems placed into orbit, as well as our educational and training pursuits (such as our rewarding work with the SAREX and ARISS projects), or our more long-term additions to the basic skills and body of knowledge in the theory and practice of the radio art and science in space.

One of the goals that Bill Tynan and I established when Bill was still President of AMSAT-North America was to look for ways to place our organization of a firmer financial footing than we had been in the past. This is not to say that AMSAT Presidents prior to Bill were playing fast and loose with member's donations. Hardly! The simple truth is that AMSAT's monetary resources have traditionally been so limited as to force our past leaders to place the organization at extreme financial risk each and every time they embarked on a new major project. In essence, they "bet the farm" hoping against hope that our members and others would continue to open their checkbooks until the project was completed.

And, so far, we've been very fortunate doing things this way, as our members and others have consistently come through for us each and every time. The simple fact that we now have the largest, most complex and most expensive satellite we've ever built (conservatively estimated to be worth \$200 Million if we had procured it commercially) sitting "flight ready" and awaiting a near-term launch opportunity is a shining example that this approach can work. However, the fact that these same AMSAT groups aren't also fiscally bankrupt right now as a result this project is the other major miracle of Phase 3D! Believe me, it has been "touch and go" on more than one occasion in that respect.

Let me again emphasize that it is each and every one of you who have so graciously supported this project, through the good times and bad, that has allowed us to continue turning the dream of Phase

3D into reality. Unfortunately, we still aren't totally "out of the woods" financially with Phase 3D just yet, as we are still pulling substantial funding from our dwindling cash reserves to help support the final testing and launch of the satellite. Your continued (and generous) donations to the cause are helping us to keep that drain manageable...at least for now. Needless to say, your help is still needed, and, believe me, it is greatly appreciated.

One of the other ways we've recently been exploring to help put our organization on a firmer financial footing is by sharing our experimenter's vast knowledge of small satellite development and operations with other non-profit organizations in return for substantial donations to AMSAT. This is a long term effort that is now beginning to ramp up. However, it will take many, many years for these efforts to produce the kind of organization-sustaining cash flows we'll need to compete for even "low cost" launches and sustain us in the years ahead. Another, and far more immediate way we can build up and sustain these reserves is to also look for more creative and attractive ways that our members and others can make personal financial donations to AMSAT.

Elsewhere in this issue (page 21), our Corporate Secretary, Martha Saragovitz, has outlined a number of ways our members can help sustain our organization over time through charitable giving. Because AMSAT-North America is a 501(c)(3) charitable organization under the United States Tax Code, your gifts to AMSAT are often tax deductible for you. What's more, depending on your other financial status, and if you itemize your deductions, your gift to AMSAT could also significantly reduce your taxes.

And your gift can take many forms. Cash gifts can be given by simply writing AMSAT a check or charging your gift on VISA or MasterCard by calling Martha at our corporate office in Maryland. Or, your donation could take the form of a gift of life insurance whereby you designate AMSAT as both the owner and beneficiary of a life insurance policy, and for which you may also qualify to receive a significant charitable deduction. A gift of shares of corporate stock to AMSAT could also help you avoid paying capital gains taxes on the appreciated value of the stock and you might even qualify for an income tax deduction for the full market share of the stock at the time you donate it to AMSAT. Furthermore, and as part of your estate planning, you might even consider adding a codicil to your will naming AMSAT as the beneficiary for part of your estate.

But, regardless of how you may choose to help us financially, I strongly encourage you to consult with your own legal counsel and/or

[continued on page 31]

JAWSAT

A spaceframe/satellite called the JAWSAT Multi-Payload Adapter (MPA) has been developed by Weber State University. Once in orbit, JAWSAT is responsible for deploying the following four independent satellites:

- ASUSat1, sponsored by Arizona State University
- OPAL, sponsored by Stanford University will also house and deploy four picosatellites (StenSat and three picosatellites from Santa Clara University).
- Falconsat, sponsored by the United States Air Force Academy
- An Optical Calibration Sphere Experiment by the Air Force Research Laboratory under contract to L'Garde, Inc.

In addition, JAWSAT will also house and support two other experiments that will remain attached to the MPA frame:

- Plasma Experiment Satellite Test (PEST) by the NASA Marshall Space Flight Center
- Attitude Controlled Platform (ACP) by Weber State University

JAWSAT Operation Notes

After deploying the various satellite payloads, JAWSAT will provide Amateur Radio communication capabilities with the following downlinks:

- 437.175 MHz Voice: 4800, 9600, 19200, and 38400 baud Gaussian Minimum Shift Keying (GMSK) digital (G3RUH compatible) at 0 to 8 watts.
- 437.075 MHz Voice: 4800, 9600 (19200?) baud GMSK digital (G3RUH compatible) at an estimated 1.5 watts.
- 2403.2 MHz Voice: 9600, 19200, and 38400 baud GMSK digital (G3RUH compatible) at an estimated 2.0 watts.

JAWSAT will allow the following two user uplinks:

- 145.xxx MHz Voice: 9600 baud GMSK digital (G3RUH compatible)
The exact uplink frequency to be announced after launch and commissioning.
- 145.yyy MHz Voice: 9600 baud GMSK digital (G3RUH compatible)
The exact uplink frequency to be announced after launch and commissioning.

JAWSAT will have 12Mbytes of RAM for data storage. In addition, the 437.075 MHz and 2403.2 MHz downlink frequencies will be experimental and will not be operational

at the same time. These downlinks will be duty cycled because of the heat they generate during operation.

Current JAWSAT operation plans call for:

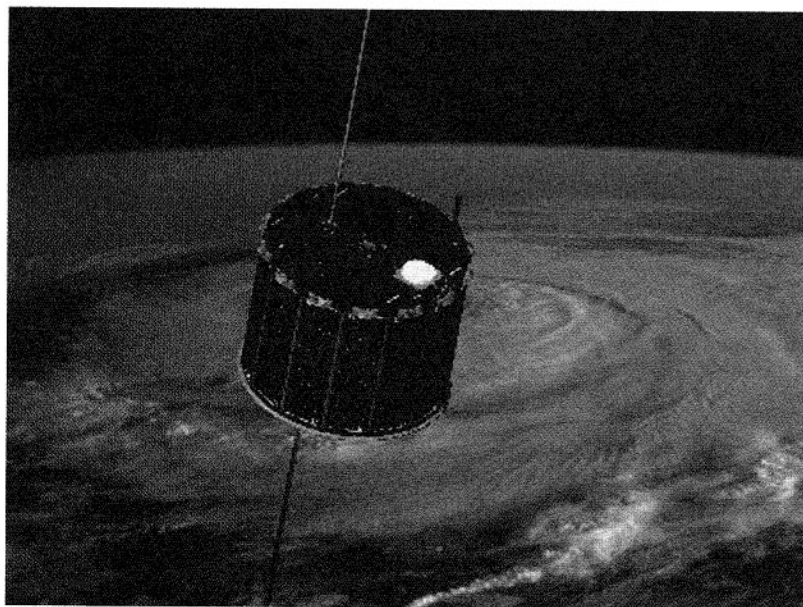
- 145.xxx MHz Voice uplink and 437.175 voice downlink with 100 Hertz CTCSS
- 145.yyy MHz 9600 bd uplink and 437.075 MHz 9600 bd or 2403.2 MHz 38400 bd downlink

Many other combinations are possible (such as 145.xxx MHz voice uplink and 2403.2 MHz voice downlink) and may be used during the orbital life of JAWSAT.

For examples of JAWSAT's orbit refer to the sample Keplerian elements on page 12. For additional JAWSAT information contact Randolph Kohlwey, N7SFI (n7sfi@amsat.org).

ASUSat1

ASUSat1 is a 12.9-pound-class student designed, fabricated, tested, and operated satellite, the first of its size (nanosatellite) to be launched as a technology demonstrator for low cost spacecraft. The satellite will provide earth imagery, a linear transponder for Amateur Radio operators, and a proof of concept for many new components. The ASUSat1 project began in October 1993 and life of the satellite will be approximately two years with images and telemetry being transmitted to an Arizona State University based ground station. Over 400 students have worked on the design of ASUSat1 since its inception. Involvement come from students ranging from high school through Ph.D. level and encompassing several science and engineering disciplines. Students from mechanical, aerospace, and electrical engineering, computer science, physics and astronomy, mathematics, art, and business have been involved. They worked on all sub-systems, including: structures, science, attitude determination & control, electronics, power, communications, software, thermal, deployment, ground support equipment (GSE), and systems. They have participated from the initial concept, through the design and instrumentation, and on through flight, ground operations, and data collection. This is an important research endeavor for science and industry that will result in many technical papers and theses. The small satellite is an important training tool for the



Artist rendition of ASUSat1 in orbit.

next generation of space scientists and engineers. The result is an intricate package of low-cost, lightweight, student-designed electronics and mechanisms that function as a complete system.

The mission of ASUSat1 has been a function of the available launch for the satellite. The goal has always been to design a 10 pound satellite to produce valuable science in space at a low cost, giving students a hands-on learning experience. The satellite was originally designed for a 450 kilometer altitude, 6 am-6 pm, sun-synchronous orbit. At this altitude, the satellite would have measured the flux, mass, velocity, and temperature of microparticles in low earth orbit with the Micro-particle Recognition Experiment (MRE). This experiment incorporated the use of a thin, piezo- and pyro-electric polyvinylidene fluoride (PVDF) film to characterize interplanetary dust and microparticles.

A new launch opportunity became available in October 1995 for a 325 kilometer altitude, 6 am-6 pm, sun-synchronous orbit. The PVDF film would have been quickly eroded by atomic oxygen at this lower altitude. Hence, a new experiment was developed. The Ionospheric Plasma Research Experiment (IPRE) was developed, consisting of a group of integrated instruments and sensors designed to utilize solar power and ionospheric plasma for low-thrust propulsion, attitude control, and electrical power generation experiments.

The 325 kilometer altitude launch did not work out due to a diminishing weight margin. A new launch profile had to be met. The new altitude was 550 kilometers, with a 10:30 - 22:30 sun-synchronous orbit. The MRE would have worked at this altitude, but the sensor development was now far behind the satellite build schedule. The IPRE would not work now because the ionosphere is only dense enough up to about 450 kilometers to produce enough propellant to give a detectable thrust.

The new mission became one of technology demonstration and earth imagery, along with AMSAT operations. ASUSat1 currently has several low-cost, new-technology demonstration aspects incorporated into its design. These include the mostly composite structure, the student-designed array of attitude determination sensors, the Trimble GPS unit, the Maxon transmitter, the gravity gradient deployment mechanism, gravity

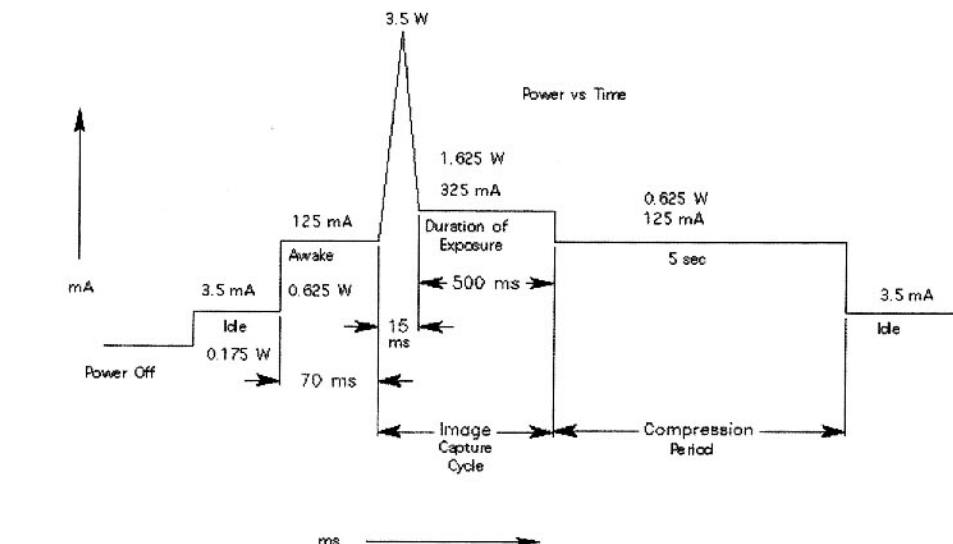


Figure 1. ASUSat1 Imaging system.

gradient fluid damper, satellite deployer, and the student-designed CPU and power boards. The satellite will also be used as a voice repeater in the amateur satellite community, and as a proof of technology for two Dycam digital cameras.

The developmental model of ASUSat1 was used for developing procedures for manufacturing the flight satellite. This first satellite has gone through shock, vibration, and functional tests. The second (qualification) satellite was completed in June 1997 and has been put through 125 percent of expected launch loads, including shock, vibration and static (survived over 20 g's static!!). Many other tests have been performed on the structures including, pyro shock, deployment, thermal and various other tests.

ASUSat1 Science

The ASUSat1 science subsystem consists of two Dycam cameras. The Dycam MODULAR digital camera system is essentially a camera electronics board that takes one picture at a time and transmits it to the host computer upon request. With each camera having its own processor and memory (1 Megabyte each), these *smart* cams automatically compress the images and store them until they are ready to be dumped to the commands board (Figure 1).

Two cameras are daisy-chained inside a single compact anodized aluminum housing measuring approximately 2in x 2.5in x 6.5in and weighing 14oz. It is bolted to the bottom bulkhead and L-bracketed to the top bulkhead and panel 14 thus eliminating the need for epoxy. Each camera consumes a

mere 5 volts and will operate in a sleep mode for most of the time drawing only 3.5mA. During awake mode the cameras use 125mA and will spike to roughly 650mA for about 15 milliseconds during the image capture.

Each camera has a resolution of 496 x 365 giving a clarity of approximately 0.5 km/pixel at our altitude of 750 km. The first camera is color and has the ability to pick up the visible red and near infrared spectrum at approximately 600nm - 800nm. The second camera will be a gray scale and will employ the use of a short pass filter in the visible blue spectrum picking up the wavelengths between 420nm - 550 nm.

With the aid of various departments at Arizona State University, image applications will vary from the main function of vegetation indexing to coastal mapping and cloud analysis.

ASUSat1 Communications

The primary goal of the communication subsystem is to provide a bi-directional RF link between ASUSat1 and ground stations (Figure 2.). This link allows the transmission of commands to the satellite and reception of scientific data or telemetry from the satellite. For this primary goal, communication will be Direct Frequency Modulation using mode J (HDLC) controlled packet transmission at 9600 baud. The uplink frequency for voice communication is 145.xxx MHz. The downlink frequency is 436.700 MHz. A secondary goal is to provide a voice repeater for the Amateur Radio community that uses mode J frequency modulation; however, voice instead of packet transmission is used

OPAL

The Orbiting Picosatellite Automatic Launcher (OPAL) is Stanford University's second Satellite QUICK Research Testbed (SQUIRT) satellite. As part of the Space Systems Development Laboratory (SSDL) the SQUIRT project exposes graduate level students to all aspects of satellite design, construction, testing, and operations. Each SQUIRT satellite is planned to complete construction in one year and cost only \$50,000. OPAL's primary mission is to demonstrate the feasibility of launching multiple picosatellites (such as StenSat) from a mothership satellite. The satellite's secondary payloads are an accelerometer testbed and a magnetometer testbed, which will perform component characterization.

Spacecraft Bus

OPAL is a hexagonal prism, made of quarter-inch aluminum honeycomb panels. The spacecraft uses a modular, three-tray approach. Each tray contains a different subsystem. In addition, all major components are shielded from EM interference inside sheet aluminum boxes.

- Bus Height is 23.5 cm (9.25in) plus three inches for launch interface.
- Boom Length: 3 inches
- Outside Radius: 21.0 cm (8.25 in)
- Mass: 52 lbs
- Volume Envelope: 27,300 cm³ (1660 in³)
- Usable Volume: 21,300 cm³ (1300 in³)

Power Subsystem

OPAL is powered by seven solar panels with ten re-chargeable Nickel-Cadmium batteries providing backup power.

- Solar Cells: GaAs, Ge
- Batteries: Sanyo KR5000DEL, D-size rated at 1.2 Volts and 5 Amp-hours

Onboard Computer

OPAL's computer consists of a primary CPU board and two peripheral data acquisition boards. All three boards are produced by Vesta Technologies. The

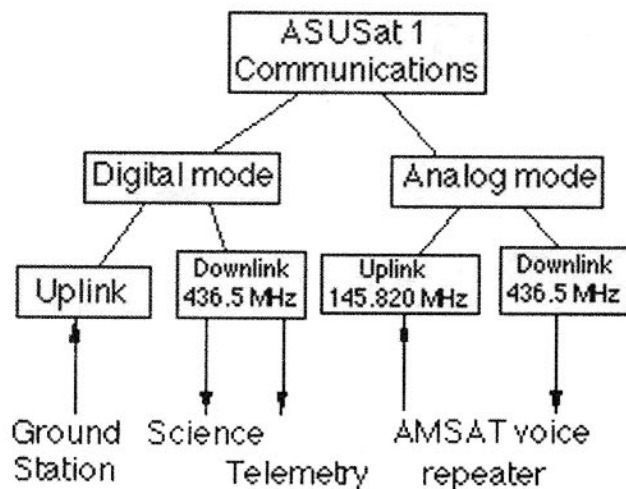
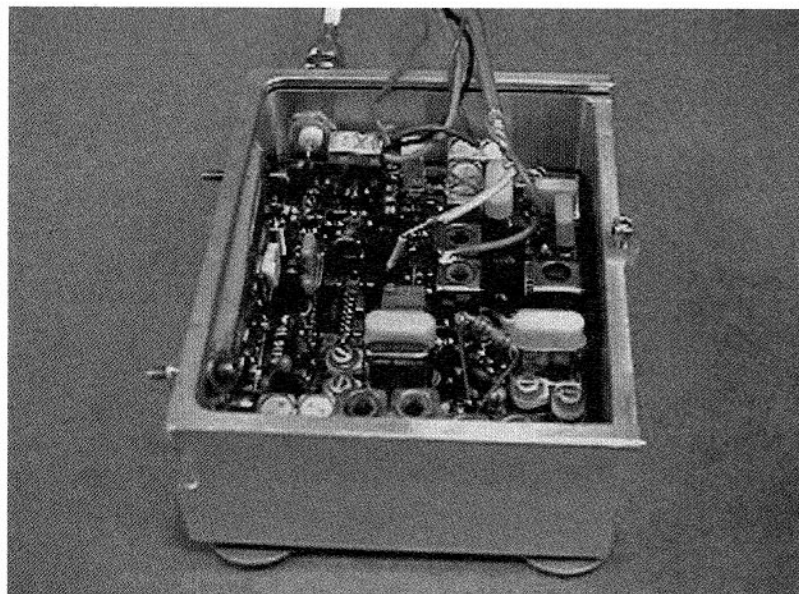


Figure 2. ASUSat1 communication modes.

and therefore the on-board modem is not utilized. This RF link is composed of two segments which are the ground segment and the space (on-board) segment. On board communication is composed of a transmitter, two receivers and a modem. The on board transmitter uses direct frequency modulation of a 436.700 MHz carrier using the modem's output to produce narrow band frequency modulation (NBFM). Two onboard FM receivers will operate at separate frequencies within the 2 meter band allowing the dedication of receiver #1 for the digital mode and receiver #2 for voice mode. The modem will operate at 9600 baud using Gaussian minimum shift keying (GMSK). This modem will serve as an interface between the command and communication boards by controlling the data flow using

HDLC frame protocol. The ground station consists of a transceiver and antenna which are computer controlled using a Terminal Node Controller (TNC) and satellite tracking hardware with software. The transceiver operates half duplex on both VHF and UHF bands. The antenna is boom mounted and automatically controlled. The automation is performed using WiSP with supporting hardware to control antenna elevation and azimuth as well as correct for the inherent Doppler shift. A reset box is connected to the TNC to send a special code to reset the commands board on the satellite in case it fails.

For additional details on ASUSat1 contact Assi Friedman, 4X1KX/KK7KX (assib@asu.edu). Also see "ASUSat1: A Low-Cost AMSAT Nanosatellite" in the



ASUSat1 transmitter

computer controls all aspects of the satellite's operation, including picosatellite launch, sensor data collection, ground communications, and engineering telemetry.

- Primary CPU board: SBC332 based on the Motorola 68332 microcontroller, running at 8.38 MHz with 1 MB of onboard RAM.
- Peripheral boards: Two SPI332 boards based on Motorola's Serial Peripheral Interface bus and protocol. Each board contains 16 digital I/O channels and eight 12-bit analog-to-digital converters.

Communications Subsystem

For ground communication, OPAL uses packet radio transmissions over amateur radio frequencies. The terminal node controller (TNC) and radio transceiver are off-the-shelf units provided by NavSymm Inc.

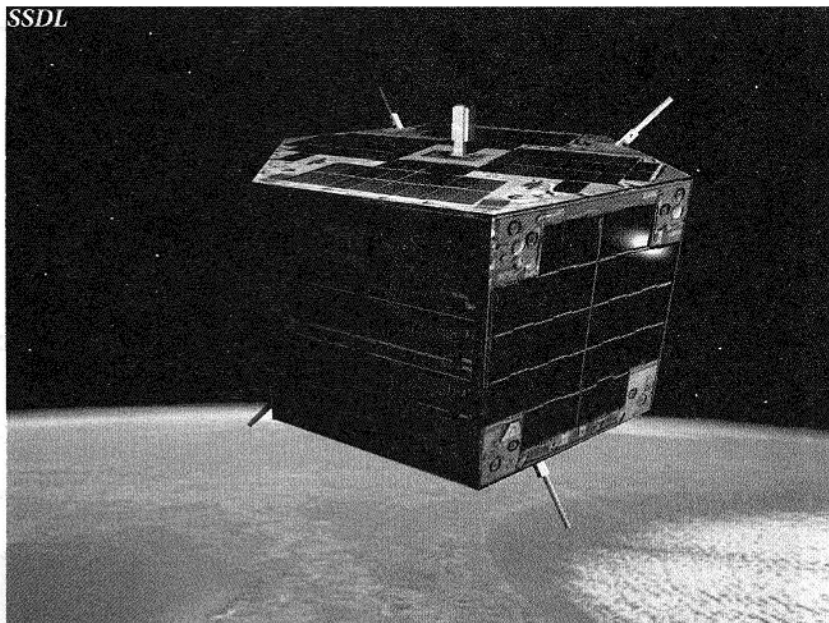
- Uplink: 70 cm band (420-450 MHz)
- Downlink: 70 cm band (420-450 MHz)
- Data rate: 9600 baud

Picosatellite Payload

The primary mission of the OPAL picosatellite payload is to provide an end-to-end mission demonstration of mothership and daughtership technologies. A storage, deployment, and communication scheme will be designed and implemented on the OPAL satellite. The OPAL mothership will store and deploy at least three picosatellite daughterships. Upon deployment, the picosatellites will establish a link with an Earth-based ground station and transfer its mission data.

Three teams have designed and constructed daughterships. A team from DARPA, Aerospace Corp., and UCLA will test MEMS technology and an intersatellite communication network. An undergraduate team from Santa Clara University will use an iterative design process to continually explore the technical capabilities and mission applications of picosatellites. An Amateur Radio team has built StenSat, a transponder picosatellite.

The OPAL design team has developed a scalable, producible, and dependable picosatellite launch mechanism. A joint



Artist rendition of OPAL in orbit. Note the daughtership satellite storage bays on the left facing panel. The bay holding StenSat is in the lower right bay.

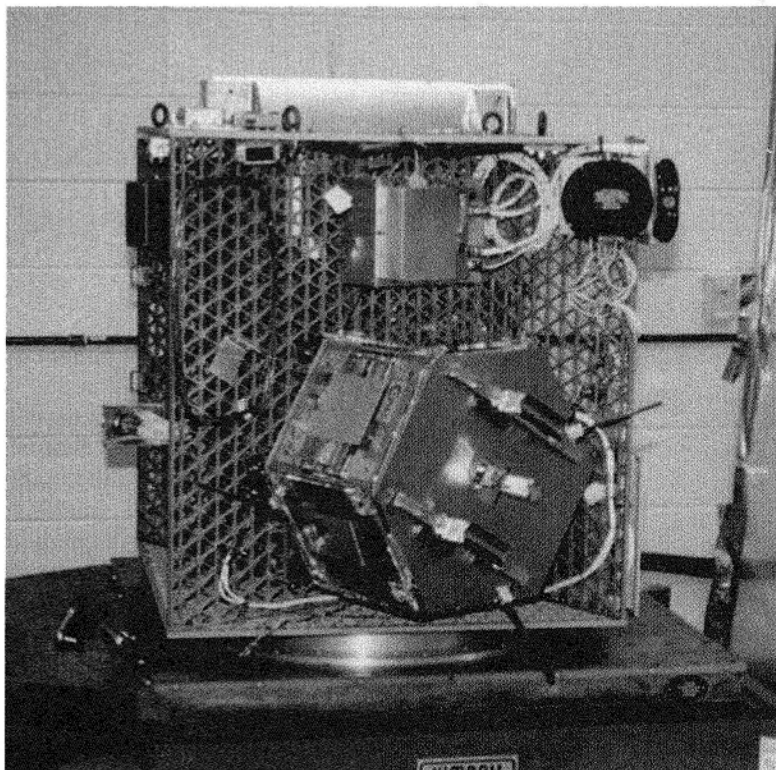
OPAL and picosatellite design team has developed the daughtership communication scheme.

Other OPAL Systems and Operations

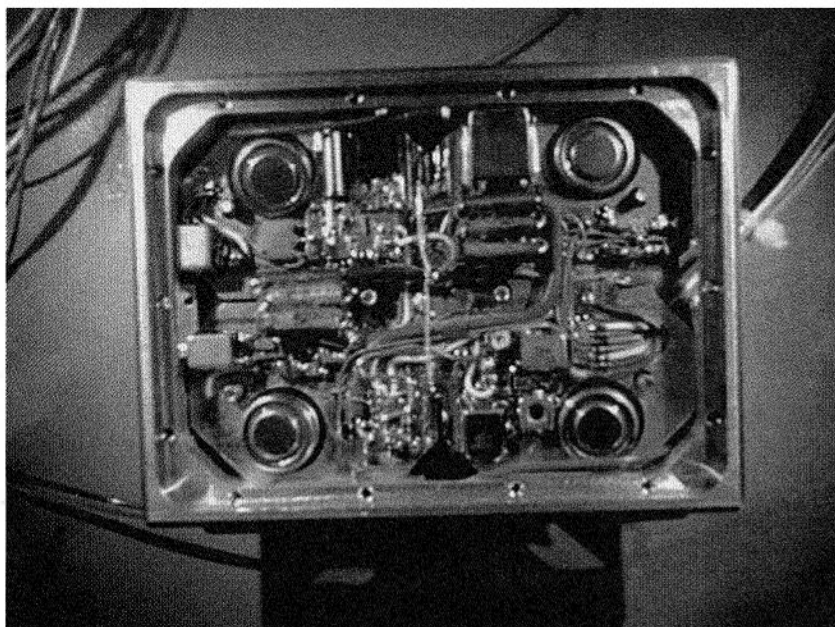
- Accelerometer Testbed: The accelerometer testbed will characterize the functionality and operation of several commercial-off-the-shelf (COTS) accelerometers. Accelerometer technologies that will be

flowed include a MEMS capacitive sensor, piezoelectric sensor, an inductive sensor, and a piezoresistive sensor.

- Magnetometer Testbed: The testbed consists of a magnetometer made by Applied Physics Systems, and is sponsored by the Relativity Mission, Gravity Probe B. The testbed will characterize the functionality and



OPAL satellite integrated to the JAWSAT MPA.



StenSat's transceiver.

operation of the magnetometer and may be used to gather OPAL attitude information.

- **Attitude Control:** OPAL is a free-flyer and performs no attitude control. The spacecraft will include ballast so its major moment of inertia is optimal for picosatellite launch.
- **Mission Operations:** OPAL will be operated from the SSDL ground station, which is fully equipped to carry out satellite contacts over the Amateur Ra-

dio satellite bands. After the on-orbit checkout period, the picosatellite payload will be the focus of operations followed by an evaluation of the test-bed payloads. Once all the experiments are completed operations will turn to an extensive analysis of vehicle performance. This will provide valuable information for future SQUIRT-class satellite development.

- **Industry Partners:** Industry involvement has been critical to the OPAL project. The following companies

have provided invaluable support and advice: Amp, Analog Devices, Analytical Graphics, Dow Corning, Eagle Picher, Harris Semiconductor, ITT Cannon, Lockheed Martin, Motorola, National Semiconductor, PacComm, Pads Software, Penstock, Raychem, Shur-Lok, Space Electronics, Space Systems/Loral, Stanley Tools, and the TiNi Alloy Company.

For additional information on OPAL contact Bob Twiggs, KE6QMD (btwiggs@leland.stanford.edu)

StenSat

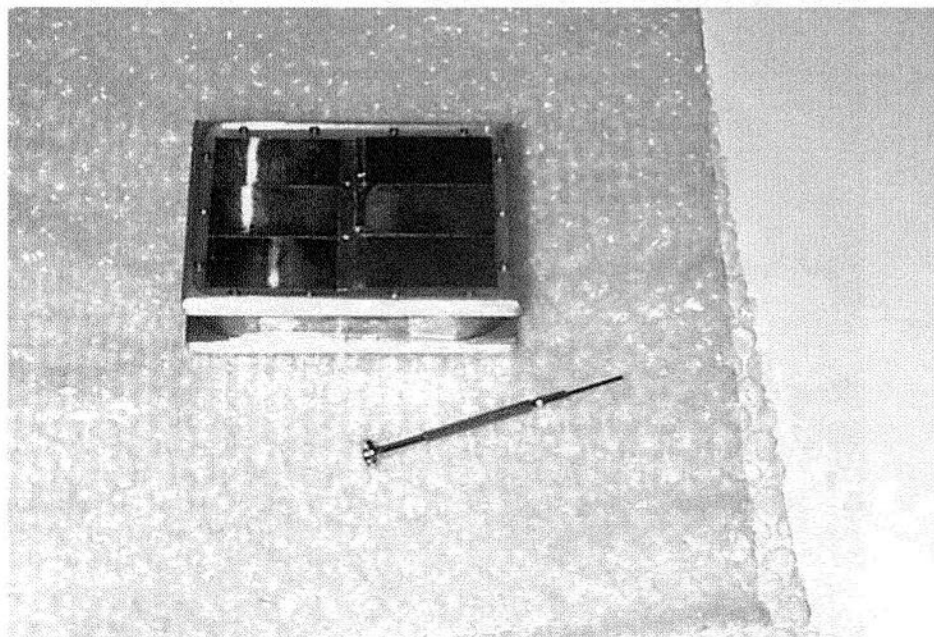
StenSat is a very small (12 cubic inch, 8.2 ounce) satellite which is intended for use by Amateur Radio operators worldwide. It will operate as a single channel mode JFM voice repeater. StenSat was built by a group of Amateur Radio operators who live in the Washington, DC area (Hank Heidt, N4AFL; Kevin Doherty; Carl Wick, N3MIM; Jim McGuire, David Niemi; Dan Schultz, N8FGV; Chris Rogers; and Steve Lim) and is a part of Stanford University's Orbiting Picosatellite Automated Launcher (OPAL) project.

The entire StenSat team designed the satellite by tossing out ideas, arguing about them, doing lots of research on the Internet and by sending innumerable emails back and forth. StenSat is named after Stenhouse, a large rambling (circa 1910) poorly maintained house without air conditioning, where several team members lived shortly after college and have fond memories of sub-orbital tennis ball launchers, rail guns and other engineering experiments.

StenSat will be released from OPAL as a test and demonstration of mothership/daughtership technology. StenSat uplink frequency will be 145.840 MHz and the downlink will be 436.625 MHz. StenSat will periodically transmit 1200 baud AX.25 for transmitting telemetry. Additionally, Amateur Radio operators will be able to ping the satellite by transmitting a six-digit DTMF command to the receiver uplink. Amateur Radio operators are asked to send StenSat telemetry reports to Hank Heidt, N4AFL at hheidt@erols.com.

Telemetry

Default telemetry for StenSat is once every 5 seconds. This may be changed by DTMF command to once every 120 seconds. When



A mass model of StenSat. Note the relative size of StenSat next to a precision screwdriver. StenSat is only 12 square inches in size. This page of *The AMSAT Journal* is 93.5 square inches while StenSat is roughly the same dimensions of this figure!

telemetry is transmitted, the receiver squelch control is turned off (low).

The normal telemetry packet looks like: *N4AFL-1TELEMC:T#000,255,004,037,129,032,010 STENSAT PICOSAT* where the Telemetry numbers are (in order):

- The sequence number goes from 0 to 255, then rolls to zero
- Power supply monitor
- Current monitor
- Temperature monitor
- 2.5 volt reference
- Current RSSI value
- Three light sensors (low value means sunlight is striking the sensor)

Additional packet trailer will appear when requested with the report extended packet command:

**CH X000 B000 L000 000 000 R032 D128* where:

- X is the radiation checksum (nominally zero)
- B is the reboot counter - incremented each reboot
- L is the three light sensors connected to B7, B6, B5
- R is the RSSI threshold
- D is the antenna release threshold

A Morse code ID will also be sent every four minutes (240 seconds). The current ID is: *STENSAT DE N4AFL/1*

Transmitter

The FM narrow band voice repeater is based on the Motorola MC13136 receiver and MC13175 transmitter pair. The uplink is on 2 meters and the downlink is on 70 cm. The receiver is located on the outer copper cladding of the top internal circuit board to provide maximum isolation from the controller.

The transmitter shares the top internal circuit board with the receiver. The output of the MC13175 transmitter is used to drive a RF Micro Devices RF2155 3v programmable gain power amplifier. The controller will set the power amplifier to one of following power levels:

- Low power (100 mW)
- High power (250 mW)

Antennas

The antennas consist of two (2m and 70cm) center fed dipoles that are made of 1/2 inch wide spring steel measuring tape. The antennas wrap around the perimeter of the satellite in a 1/8 inch deep racetrack and are held in the racetrack with (four pound test strength) fishing line. The antennas are released by shorting a AWG 38 nichrome wire (for 1 second) after the batteries are fully charged. The nichrome wire melts the fishing line releasing the antennas.

Controller

The controller is implemented using a modified Clement Engineering MIM v2.0 (based on the Micro Chip PIC16C73A) and

a California Micro CM8870 DTMF decoder for command control. The modified Clement MIM provides the following functionality:

- External watch dog reset
- Antenna release (by pulsing nichrome wire to melt release line)
- Morse Code Identification
- AX.25 telemetry
- Command Processing (from CM8870 DTMF chip)
- Digital sun sensor inputs (3)
- Set TX power level (High/Low)

The controller is connected to a Linear Technology LTC694-3.3v Microprocessor Supervisory Circuit that acts as a low



Insertion of StenSat into one of OPAL's daughtership bays.

voltage cutoff monitor and as a 100ms external watchdog timer to help protect against RAD latchups. The controller uses switching FET's to control the antenna release, TX power level, RX squelch (RSSI) and the main power bus. The controller is located on the bottom internal circuit board.

Components

- Aluminum chassis (four inches by three inches by one inch) with antenna racetrack
- Magnet
- Top and bottom printed circuit board solar cell panels

- Two internal printed circuit boards (receiver / transmitter and controller)
- Black and white paint

One NdFeB disk magnet provides alignment and attitude control. Painting different sides of one of the dipole antennas with black and white paint will introduce a slow radiometric spin.

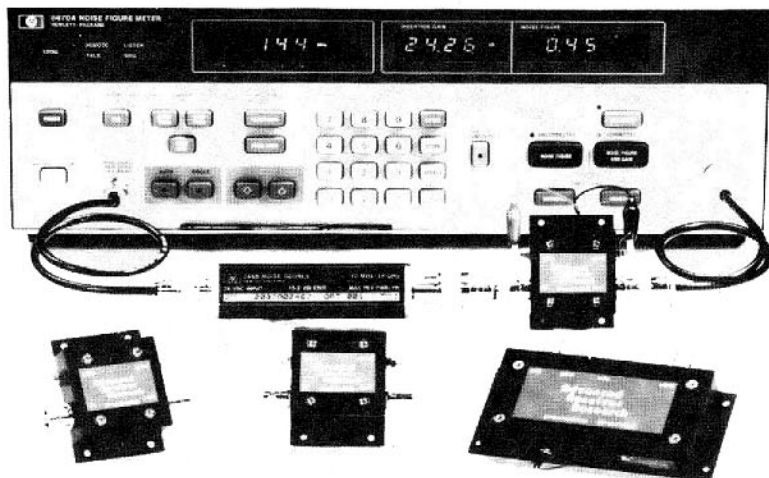
Power

Power is supplied by the top and bottom panel of six GaAs solar cells each of which is used to provide an unregulated main bus voltage of between 3.0 and 4.1 volts under our minimum bus current load for the receiver and controller. The solar cells are connected directly to three 1.2 volt 1/3 Af NiCAD 220 mAh batteries that are connected in series. Schottky diodes are used to protect the two panels. A Linear Technology LCT694-3.3v Microprocessor Supervisory chip is used to switch the controller and transceiver off when the bus voltage drops below about 3.0 volts. A National Semiconductor LM431 Precision Zenor Shunt Regulator is used to provide battery overcharge protection.

Sensors

- Temperature: Will be measured with a Telcom Precision TC02 temperature to voltage converter that is connected to one of the PIC16C73A A/D pins.
- Current: Bus current will be measured with a Maxim MAX4172 Precision High-side Current Sense Amplifier connected to another A/D pin.
- Voltage: Bus voltage will be measured by comparing the output of a 2.5 volt Linear Technology LT1004 Micro-power Voltage Reference that will be connected to another A/D pin.
- RSSI: The receiver RSSI output of the Motorola MC13136 is input to another A/D pin.
- Sun Sensors: StenSat has three phototransistors connected to three of the PIC16C73 digital pins. The sun sensors are located on the bottom panel, the left side and top side.

High Performance vhf/uhf preamps



Receive Only	Freq. Range (MHz)	N.F. (dB)	Gain (dB)	1 dB Comp. (dBm)	Device Type	Price
P28VD	28-30	<1.1	15	0	DGFET	\$29.95
P50VD	50-54	<1.3	15	0	DGFET	\$29.95
P50VDG	50-54	<0.5	24	+12	GaAsFET	\$79.95
P144VD	144-148	<1.5	15	0	DGFET	\$29.95
P144VDA	144-148	<1.0	15	0	DGFET	\$37.95
P144VDG	144-148	<0.5	24	+12	GaAsFET	\$79.95
P220VD	220-225	<1.8	15	0	DGFET	\$29.95
P220VDA	220-225	<1.2	15	0	DGFET	\$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	\$79.95
P432VD	420-450	<1.8	15	-20	Bipolar	\$32.95
P432VDA	420-450	<1.1	17	-20	Bipolar	\$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	\$79.95
Inline (rf switched)						
SP28VD	28-30	<1.2	15	0	DGFET	\$59.95
SP50VD	50-54	<1.4	15	0	DGFET	\$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	\$109.95
SP144VD	144-148	<1.6	15	0	DGFET	\$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	\$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	\$109.95
SP220VD	220-225	<1.9	15	0	DGFET	\$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	\$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	\$109.95
SP432VD	420-450	<1.9	15	-20	Bipolar	\$62.95
SP432VDA	420-450	<1.2	17	-20	Bipolar	\$79.95
SP432VDG	420-450	<0.55	16	+12	GaAsFET	\$109.95

Every preamplifier is precision aligned on ARR's Hewlett Packard HP8970A/HP346A state-of-the-art noise figure meter. RX only preamplifiers are for receive applications only. Inline preamplifiers are rf switched (for use with transceivers) and handle 25 watts transmitter power. Mount inline preamplifiers between transceiver and power amplifier for high power applications. Other amateur, commercial, and special preamplifiers available in the 1-1000 MHz range. Please include \$2 shipping in U.S. and Canada. Connecticut residents add 6% sales tax. C.O.D. orders add \$2. Air mail to foreign countries add 10%. Order your ARR RX only or inline preamplifier today and start hearing like never before!

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For additional StenSat information, see <http://www.erols.com/hheidt> ■

Selecting a New Auxiliary Battery for Phase 3D

Gerd Schrick, WB8IFM

Phase 3D has been in the construction stage for almost ten years. Technology does not stand still. State-of-the-art design at the beginning of Phase 3D construction has matured and new developments and designs have appeared. Of course, being more flexible and receptive to new items, the builders of Phase 3D have added new things and made scores of minor and major changes. A 24 GHz TX and a new second internal housekeeping processor (YAHU) come to mind. But most of the improvements are incremental and in the mechanical and thermal design area to make the spacecraft survive the rigors of the launch and the hostile environment of space.

All this has caused an increase in size and weight to the point where a launch or achieving of a desirable orbit becomes a big question mark. So we have been looking for ways of *losing weight*.

A big pay-off in that regard opened up with the decision to switch cells in the auxiliary battery from NiCds to Nickel Metal Hydride types. Those cells, available for some time, but expensive and not proven, are now quite reliable and have become affordable as well. They provide almost twice the capacity of the same size Nicads and would allow us to halve the number of cells in the battery, thus saving considerable weight.

Stan Wood, WA4NFY, who meticulously keeps track of all the bits and pieces that go into Phase 3D, recognized this as a real contribution, rather than nibbling around the edges, as with other weight saving measures.

As with all batteries, it is essential that all the cells in the string are closely matched in their charge and discharge characteristics. A lot depends on a well-controlled manufacturing process, but for space application a further refined selection is called for to extend the life of the battery to a maximum. From a batch of 50 cells we selected 20 plus 5 spares for the satellites auxiliary battery. [The cells were Nickel Metal Hydride types with nominally 20 AH capacity made in China]

The selection process consisted of assembling 25 cells in series to form a battery and wiring each cell to a switch so that the voltage across each cell could be monitored in sequence. A relay arrangement would have been too involved, so two

manually operated switches (1 ea. 2x12 and 1 ea. 1x3) were used. Even so, it took two of us (Hermann Guenther was of great help) almost a full day to wire the test set (see photograph). Though switching the cells was done manually, Rick Leon, KA1RHL, wrote a computer program to record the voltmeter readings, down to the millivolt and plot the curves. The operator was prompted by a beep to turn the switch to the next cell. A complete one-time reading of the 25 cells took about 50 seconds.

In the week of testing the beeping out of the corner of the lab became a familiar sound to all. This manual switching had to be done every few minutes at the beginning and at the end of the cycle while during the middle every half or even full hour would do. Since time was of the essence we went with capacity/5 = 4A for the charge and discharge currents. Even so a complete cycle (charge and discharge) took about ten hours. Since the battery got hot from a charge and needed cooling off some, a day's cycle was usually started with a discharge followed by a charge in the afternoon. For a few days I would be the first one to come in the morning and the last one to leave at night. Of course, during that time I had some one-hour breaks for lunch and other things. Figures 1 and 2 show the typical charge and discharge characteristics of the cells. At the end of the charge the cell voltage rises to a maximum then drops a little. At that point the temperature, which we monitored for just one cell in the string, rises sharply since

the constant current still supplied, now causes heating only. That is the time to terminate the charge. Nominal discharge is reached, when the cell voltage drops below one Volt.

We had thought of a *clever* method to quickly connect and disconnect a load resistor across each individual cell using a bank of switches. The added wires, however, contributed so much resistance to the nominally 0.3 Ohm load that a controlled discharge was impossible. Another example that Ohm's Law cannot be ignored. Penitent, we went back to the *alligator* approach, originally suggested by Chuck Green, N0ADI. We soldered, however, one side of the load resistor to one side of the individual cells.

It turned out that the cells were matched relatively closely in their characteristic, which would indicate a good consistency in the manufacturing process or some prior selection. All cells were relatively close, but since we were measuring in minutes and millivolts we could still distinguish and rank all cells nicely.

Looking at two times 25 three-digit numbers and rearranging them by size is not everybody's strength. Karl Meinzer, DJ4ZC, however, juggled the numbers quickly, and while I was still scratching my head, had ranked them all and we were able to pick the 20 finalists and 5 spares. The spares were needed because there was still

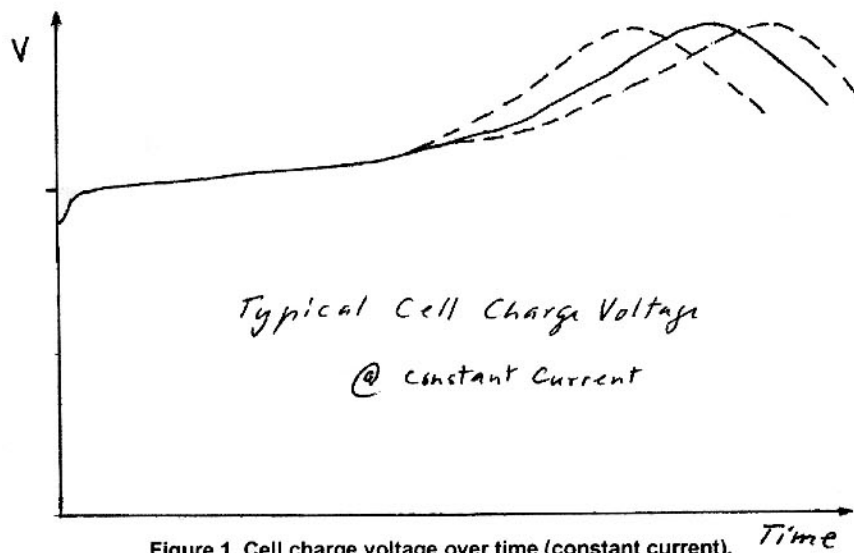


Figure 1. Cell charge voltage over time (constant current).

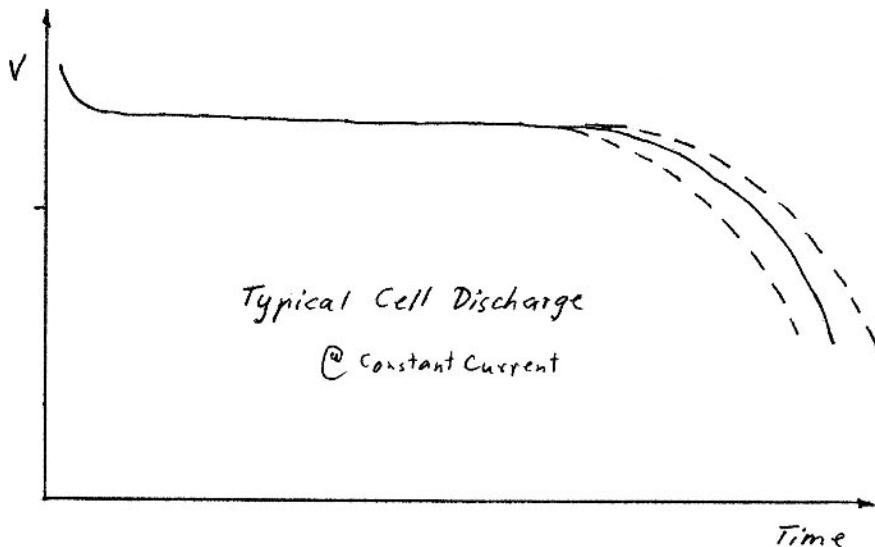


Figure 2. Cell discharge voltage rate over time (constant current).

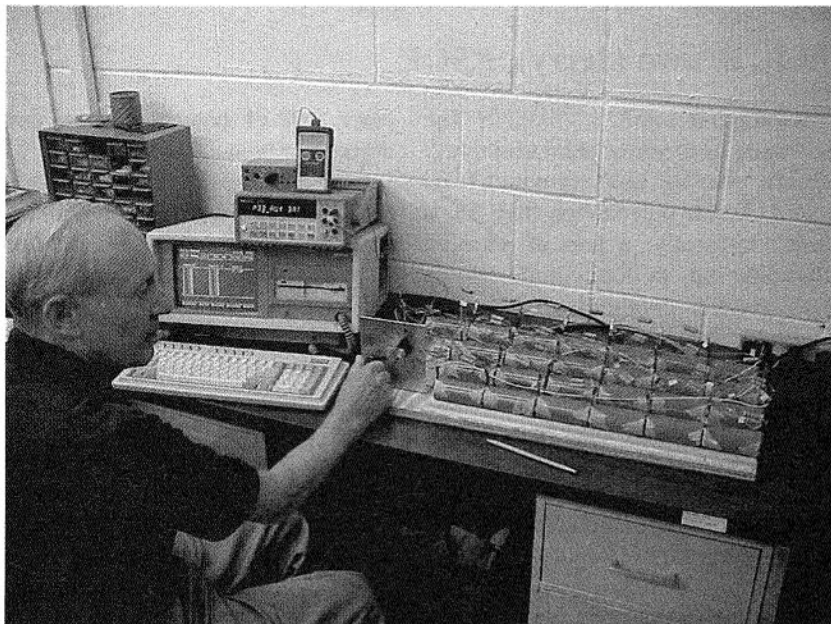
the possibility that a cell (or two) might be eliminated for other reasons. The string of 20 cells went through a final cycle and was then left uniformly discharged.

All the nice blue plastic wraps were removed from the chosen cells, as was the plastic insulation of the strips for positive and negative poles. This exposed the bare steel cases of the cells, which were inspected for any damage. Fortunately none was found. The positive straps were bent up to prevent shorting in the further handling. Next the cells were thoroughly cleaned using distilled water and alcohol, the objective was to remove any remnants from the manufacturing process in particular the electrolyte, potassium hydroxide, KOH. After this a leak test was performed using a solution of phenolphthalein (1g in 60% alcohol) which turns pink in the presence of even a minute trace of a base like KOH. Karl

Satellite Orbital Elements

By Ray Hoad, WA5QGD

Satellite	AO-10	FO-20	RS-12/13	RS-15	FO-29	AO-27	UO-11	MIR
Catalog Number	14129	20480	21089	23439	24278	22825	14781	16609
Epoch Time	99251.34334146	99252.07077681	99251.93214545	99252.10059490	99251.86622156	99252.15532281	99252.91114364	99253.47551400
Element Set	588	179	184	416	281	755	188	861
Inclination	27.1955	99.0226	82.92	64.8155	98.5687	98.4512	97.9403	51.6596
RA of Node	10.9982	70.8128	35.1244	276.7065	191.8589	314.091	217.1209	266.8598
Eccentricity	0.6021626	0.0540557	0.0028448	0.0160831	0.035077	0.0009247	0.0010486	0.0004494
Arg of Perigee	345.2426	334.5152	189.229	337.8715	237.4771	18.3531	284.6129	345.1392
Mean Anomaly	2.8527	23.017	170.8346	21.5318	119.2026	341.799	75.389	14.9438
Mean Motion	2.05868459	12.83255735	13.74144099	11.2753304	13.52678609	14.27934735	14.70706017	15.72414354
Decay Rate	-0.00000263	0.0000002	0.00000103	-0.00000042	0.00000033	0.00000158	0.00001378	0.00020799
Epoch Rev	12210	44909	43091	19370	15112	31022	83094	77483
Satellite	AO-16	DO-17	WO-18	LO-19	UO-22	KO-23	KO-25	ISS
Catalog Number	20439	20440	20441	20442	21575	22077	22828	25544
Epoch Time	99252.16024199	99253.25078703	99252.15258971	99253.72913098	99252.66978321	99252.09198099	99253.71193220	99253.17491738
Element Set	264	257	288	262	970	866	727	923
Inclination	98.4773	98.4848	98.485	98.4914	98.1895	66.0848	98.4485	51.5947
RA of Node	328.3677	331.0399	329.7362	332.5369	289.1757	241.0546	316.2403	129.6213
Eccentricity	0.0011214	0.0011545	0.0011841	0.0012271	0.0007835	0.0007776	0.0010654	0.0008864
Arg of Perigee	337.471	331.5639	335.9505	329.9887	334.4934	202.7048	354.627	309.1416
Mean Anomaly	22.598	28.4899	24.1124	30.058	25.5865	157.3627	5.4792	50.8783
Mean Motion	14.30249397	14.30410288	14.30352982	14.30483711	14.37381564	12.86327156	14.28433898	15.6253504
Decay Rate	0.00000246	0.00000253	0.00000194	0.00000217	0.00000306	-0.00000037	0.00000193	0.00014597
Epoch Rev	50257	50277	50261	50287	42747	33243	27862	4587
Satellite	IO-26	TO-31	GO-32	SO-33	PO-34	SO-35	UO-36	JAWSAT (Est)
Catalog Number	22826	25396	25397	25509	25520	25636	25693	32766
Epoch Time	99252.19838661	99252.19837316	99252.16063218	99251.63161989	99252.17774630	99252.19143272	99253.88603030	99289.07604166
Element Set	758	193	235	81	97	102	65	1
Inclination	98.4534	98.7537	98.7544	31.4429	28.4632	96.4797	64.5596	100.0000
RA of Node	314.6375	325.168	325.0283	43.3541	257.9408	159.6013	243.9908	101.0000
Eccentricity	0.0009798	0.0004695	0.0001531	0.0367553	0.0007576	0.0153653	0.0018352	0.0001
Arg of Perigee	17.0609	160.9373	157.6287	140.1221	133.765	350.7204	337.8646	0.0000
Mean Anomaly	343.0895	199.2005	202.4958	222.7014	226.3563	9.1154	22.1657	180.0000
Mean Motion	14.28061055	14.22420599	14.2227022	14.24089136	15.03987671	14.40939637	14.73340103	14.42590000
Decay Rate	0.00000219	-0.00000044	-0.00000044	0.00001031	0.00001778	0.0000049	0.0000023	0.00000000
Epoch Rev	31025	6056	6057	4551	4736	2847	2100	1

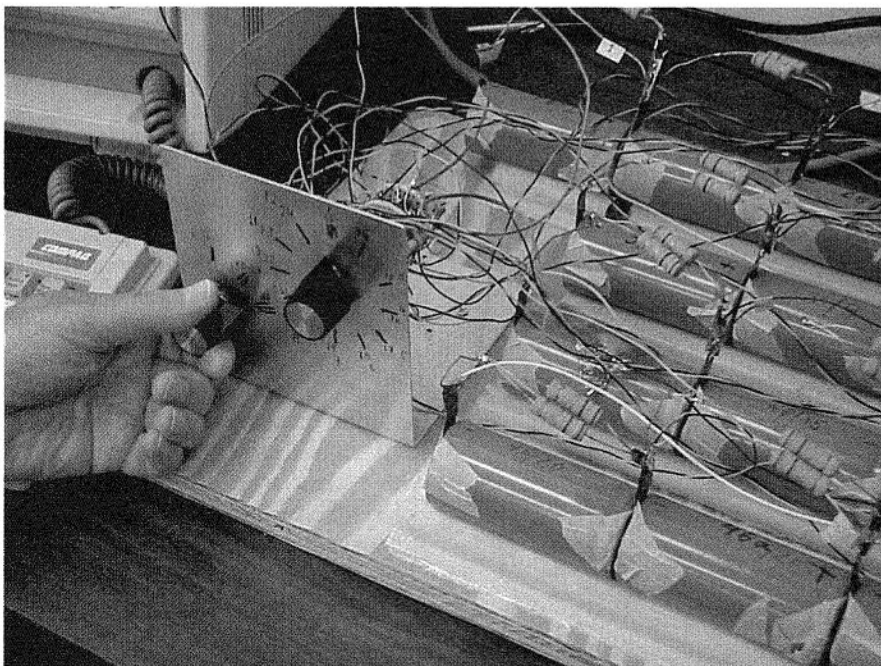


Gerd Schrick, WB8IFM discharging a test battery while monitoring individual cell voltages.
(photo by Wilfried Gladisch)

had previously, while inspecting a cell, put his tongue near the seal, then exclaimed: KOH! So the tongue is a sensitive indicator, however, this procedure is not recommended. Applying this solution carefully around the seal with a small brush a few cells showed a very minor reaction while the solution at one cell turned bright red immediately. Upon closer inspection it was found that the cell had a poorly seated seal and we eliminated it from the battery.

Next the cells had to be insulated with space qualified materials before being mounted in

their final fixture. The body of the round cell was wrapped in selfadhesive Kapton tape and top and bottom sealed with a rubbery type material. With the help of a temporary fixture the cells could be dropped slowly onto a precut and properly positioned sheet of Kapton so they would line up with the tape and could be rolled around to get it straight, a very difficult job if done the *eyeballing* way. After mounting the cells, ten to a frame, and soldering the connections, the battery was ready to join the satellite. Another step closer to launch. ■



Switching individual cells to record voltages. A semi-automatic data collection activity! (Photo by Wilfried Gladisch)

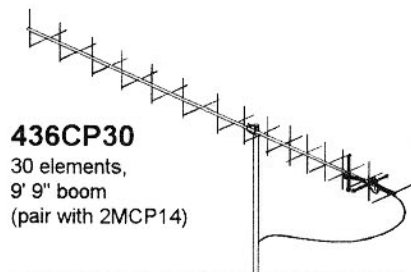
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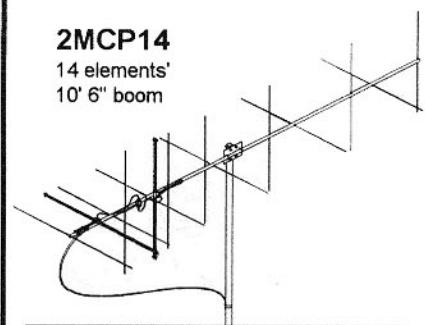
436CP42-U/G

42 elements,
18' 10" tapered boom
(pair with 2MCP22)



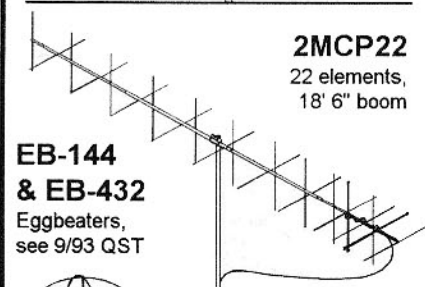
436CP30

30 elements,
9' 9" boom
(pair with 2MCP14)



2MCP14

14 elements'
10' 6" boom

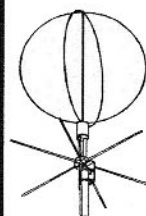


2MCP22

22 elements,
18' 6" boom

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The Eggbeater II Omni-directional LEO Antenna

Gerald R. Brown (Jerry), K5OE

Presented here is a high-performance, circularly polarized omni-directional antenna that is easy to build, easy to tune, inexpensive, and will work all the mode J Low Earth Orbit (LEO) satellites. I have built several of the traditional "eggbeaters" from plans floating around on the Internet, but was never satisfied with the overall performance. This design is the outcome of my investigations into methods of improving the performance of the *original* eggbeater without obviating the simple construction.

Background

The *eggbeater* antenna is an omni-directional antenna employing circular polarization to maximize signal capture from low Earth orbit (LEO) satellites. It is, basically, just two full wave loops fed in quadrature. Commercial versions are available from M² Antennas

(<http://www.m2inc.com/>).

The garden-variety home-brew version employs a 90-degree "phasing" line to provide a fixed right-hand circular polarization (RHCP). It also uses, optionally, a pair of parasitic reflector elements to focus more of the radiation pattern overhead. This effect makes it a *gain* antenna, but that gain is at the expense of low-elevation reception. To the horizon it is linear-horizontally polarized. As the pattern rises in elevation, it becomes more and more RHCP.

My on-the-air observations about the excellent overhead performance of the eggbeater with radials led to some hunches, followed by experimentation, and resulted in the *Texas Potato Mashers* (Jan/Feb 1999 *The AMSAT Journal*). The TPM improved the coaxial gain of the eggbeater by re-shaping the loop into a square and moving the reflector closer to the driven element. It has been my workhorse LEO antenna ever

since, but of course, it is a directional antenna.

Nevertheless, how can we improve the eggbeater as an omni-directional antenna? A couple of data points worth noting are, compared to directly overhead, a typical LEO satellite has about 6 dB in free-space path loss at 30 degrees, and another 6 dB at the horizon. This implies an ideal omni-directional antenna would have an elevation pattern that was -6 dB from 30 degrees to 90 degrees—focusing the gain from the horizon up to 30 degrees elevation—where you need it the most—but without the deep overhead null presented by high-gain verticals.

I've been pondering this design problem (how to *easily* build a better omni for satellites) ever since I read AA2TX's paper from the 1998 AMSAT Symposium ("An Omni-Directional Antenna for Receiving Mode-J, LEO Satellites"). Tony presented a novel and effective design and made several thought-provoking points. It is recommended reading. His prototype design, however, may be difficult for the average back yard mechanic (a ham with two left thumbs) to reproduce.

Design

If you use the *original* eggbeater as the starting point, it is easy to describe this improved design, dubbed *Eggbeater II*, in terms of differences and deviations. The first distinction is it does not use a round "loop" for the driven elements. Instead, rectangles are formed. Modeling showed me why the original eggbeater never had an SWR below about 1.5:1. The input impedance of the round loops with reflector was close to 90 Ohms—too low. Starting with a square and *playing* with the shape allowed me to find a very good match at 100 Ohms, purely resistive. Since the two rectangular-loops are fed in-quadrature (but out of phase), the resultant feedpoint is very close to 50 Ohms with no reactance. The antenna is linearly polarized horizontally at the horizon and the pattern becomes more and more right-hand-circularly-polarized (RHCP) as the elevation angle increases.

The second major distinction is the location of the reflector elements. They are placed not at the common 3/8-wavelength distance,

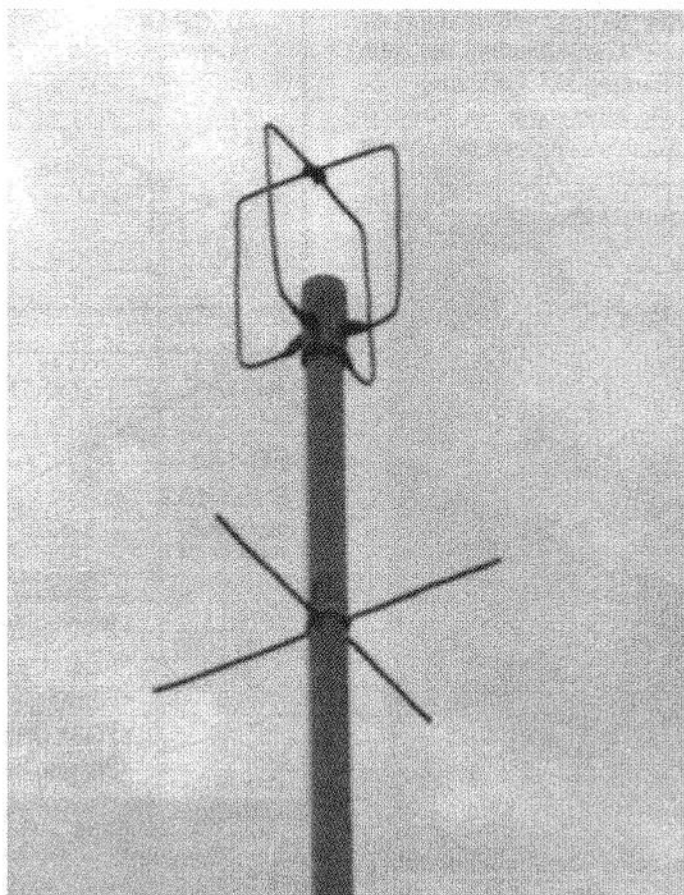


Figure 1. 70 cm Eggbeater II in use during Field Day 1999.

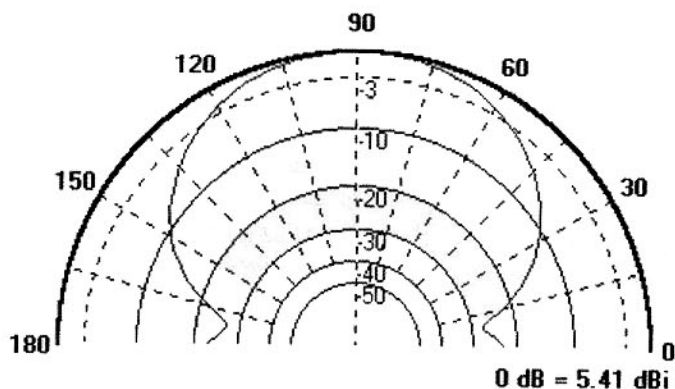


Figure 2. "Original" Eggbeater Free Space H-Plane Elevation Plot.

but at slightly more than $1/2$ wavelength below the driven elements. This placement helps *pull* the major lobes down to the horizon instead of *pushing* them overhead as in the original eggbeater design.

The free space elevation plots in Figures 2 and 3 (NEC4Win) clearly depict the improvement of the new design over the *original* eggbeater. Note the gain is almost the same at 45 degrees, but the new design is 6 dB better at 30 degrees and about 10 dB better at 15 degrees. The real-world ground-based elevation patterns are shown in Figures 4 and 5.

Of course, the trade-off is that the new antenna exhibits -10 dB directly overhead. That is by design. Remember that 6 dB is gained in reduction of the satellite's path loss and 3 dB is gained in the improved circularity of the signal as the bird reaches higher elevations. How often does a satellite go above 75 degrees? Not very often; and

the duration of its stay in that high elevation is very brief. In short, you give up very little and theory predicts an almost constant signal level from 15 degrees to directly overhead.

Construction

Common 1" PVC couplings and 6-32 stainless hardware are used. The loops are formed from #10 copper wire with insulation left on (1 strip 10/2 w/ground house wiring for the conductors, about \$6.00 for a 25' box). The 70 cm loops are 6-3/4" (17 cm) wide by 8-1/4" (21 cm) tall; the 70 cm reflectors are 13-1/4" (33.5 cm) long and 13" (33 cm) below the driven elements. The 2 meter loops are 20" (51 cm) wide by 24-9/16" (63 cm) tall; 2 meter the reflectors are 39-1/2" (100.5 cm) long and 39-3/4" (101 cm) below the driven elements. I used 3/16" aluminum rod for the 2 meter reflectors. You could also try using 1/4" copper tubing as a suitable alternative.

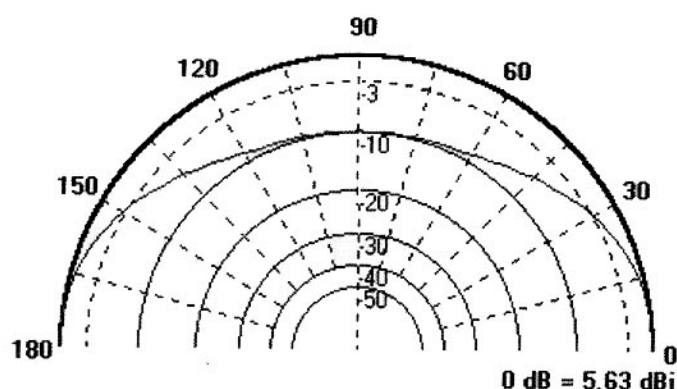


Figure 3. *Eggbeater II* Free Space H-Plane Elevation Plot.

These dimensions are very precise and will work well with #10 and #12 wire (for 70 cm only), but you may want to make the loops slightly larger and trim the extra length based on your SWR readings. The #10 wire on the 2 meter version is marginal, so using #8 aluminum wire may be a good, if difficult to work, alternative. Unlike the original eggbeater, this new design provides an almost perfect 1.05:1 SWR.

A method I've developed to test resonance of the loops is to feed both in parallel, without the phasing line; connecting the 50 Ohm feedline to both loops. This provides a good resonance test without any impedance bump from the phasing/delay line. Simply connect the coax center conductor to any two adjacent loop ends and the coax shield to the other two adjacent loop ends. With the reflectors installed, test for SWR. If the SWR is above 1.5:1, follow this procedure:

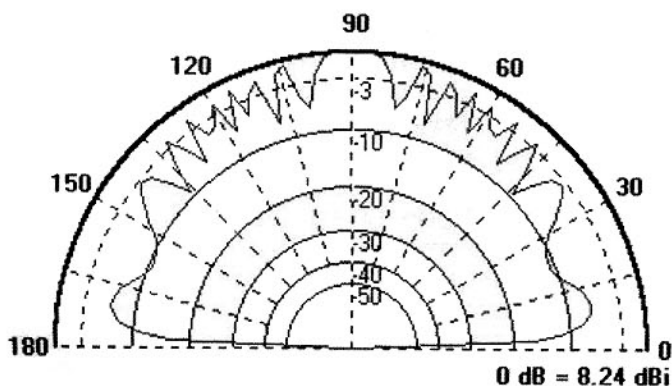


Figure 4. "Original" Eggbeater At 35' Elevation.

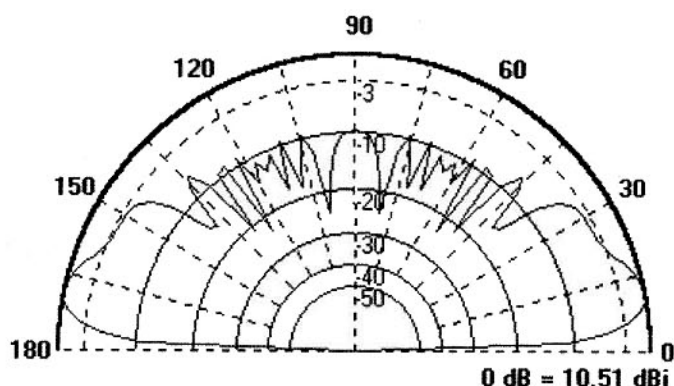


Figure 5. *Eggbeater II* At 35' Elevation.

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Ohm, see notes below) coaxial cable. The connections from the coaxial cable to the loops are made using ring lugs and stainless steel 6-32 bolts/washers/nuts; see Figure 6 for right-hand-circular-polarization connections. The 70 cm phasing line is 5-1/2" (13.5 cm) long and the 2 meter phasing line is 16-1/2" (41.5 cm) long. Cut the RG-62 about 2" (5 cm) longer than these measurements and leave 1" (2.5 cm) at each end to strip the insulation, peel back the braid, strip the center conductor, and attached the ring lugs. The ring lugs at one end of the phasing line can be shared with the 50 Ohm feedline (9913F or equivalent is recommended) so that only four ring lugs are required.

Performance

This antenna, mounted at 35' elevation, performed very well for an omni-directional design. At 5 degrees above the horizon, signals on FO-20 start to come alive. At 15 degrees, they are strong and clear—without a preamp AND with over 50' of feedline. The signals stay strong and pick up about 3-to-6 dB of strength up through 90 degrees. I believe this increase is due to the improved circularity as the pattern rises.

The signals on AO-27 are much harder to capture and the horizontal polarization at the horizon is a definite penalty. I found the use of a preamp necessary. I got good copy on the bird once it reached about 15-20 degrees elevation—compared to 30-to-35 degrees on my original eggbeater. While I have not attempted to use this antenna for pacsats, I have monitored the signals on FO-29 while in mode JD and found I could copy at S3 or better from horizon to horizon (with preamp).

RG-62 Coaxial Cable

The 93 Ohm cable is not as commonly available as RG-8 or 9913F. In a pinch, you could substitute 75 Ohm cable such as RG-6, but expect to pay a price in feedpoint balance and SWR. For the 2 meter uplink, you may never tell the difference. For the 70 cm downlink, it could mean the difference between copy and no copy.

If you cannot find any of this cable, send me (18915 Windsor Lakes Drive, Houston, TX 77094) a SASE (5x7 manila envelope with 2 units of postage recommended) and I'll cut and send you one or both of the required cables. ■

- If SWR is better at lower frequency, make the loops slightly smaller and re-test
- If SWR is better at higher frequency, make the loops slightly larger and re-test

The reflector length is very critical, so measure it accurately. The distance is not so critical and can be adjusted a small amount to get the SWR perfect.

Finally, install the phasing/delay line. The phasing lines are made from RG-62 (93

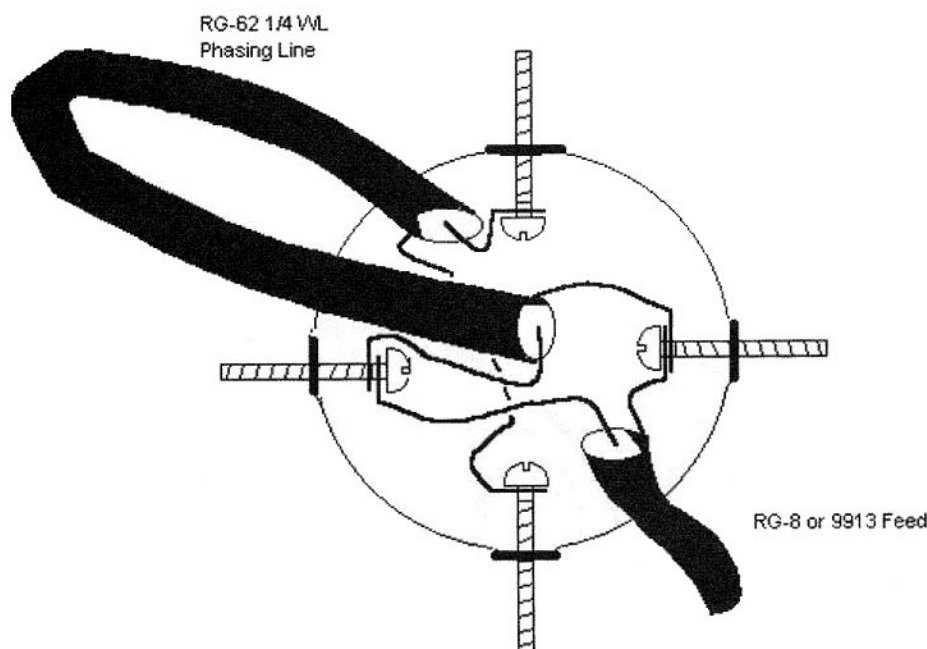


Figure 6: Coax Connections for RHCP Viewed from Bottom.

Doppler Frequency Effect on Phase 3D, Part 1

Franz J. Bellen, DJ1YQ

Translation by John J. Bubbers, W1GYD

Editor's Note: This paper, originally printed in The AMSAT-DL Journal (Vol. 25:4, Dec./Feb. 98/99), presents an overview, as to how large the magnitude of the Doppler shift can be on the different operating modes and frequencies during an orbit, in order to be able to plan the compensation range for the hardware and software.

In part two, the rate of Doppler change, that is the frequency shift over time, will be covered.

We are all agree that Phase 3D will be available and in orbit in the foreseeable future. Since the satellite has a transponder on board that covers up to 24 GHz, we should prepare our stations for the Doppler shifts in a timely fashion, which these high frequencies present.

The maximum Doppler frequency shift of a satellite signal which can occur at any time and at any place on the earth's surface, depends on the orbital period of the satellite and the eccentricity of its orbit (Figure 1). At the same time the maximum shift values lie in the orbital plane at AOS where they have their largest positive value while at LOS they have their largest negative value.

The computation method [1] for the graphics appearing below in Figures 3 to 6 is based on the assumption that during a satellite's orbit it is observed by two pseudo stations, A and B, at an elevation of zero degrees. Once the satellite has completed its orbital path, then stations A and B have also moved through their paths on the earth's surface.

This method then sets the condition, that the maximum frequency shift in the diagram does not occur at MA = 0, rather when A or B is at the perigee of the satellite's sub-position. This is always the case which occurs before MA = 256 and after MA = 0.

The computations are dependent on the boundary limit values; the curves, therefore, cannot be translated to a definite QTH. Since Phase 3D has the same orbital direction as the earth's rotation, the curves of the Doppler shift are displaced to smaller values because of the earth's rotation and, indeed, to the product of:

(Doppler shift at the equator) * cos (geographical latitude).

This means that an operator at the equator must take into account the complete value, while one at the poles experiences zero.

Result: In a worst case consideration which should be used here, to establish the range of the Doppler compensation the earth's rotation can be ignored.

The magnitude is presented in the graphics, however not considered in the curves.

Doppler Shift of Phase 3D

Since the launch time cannot be predicted by AMSAT, the satellite requires an orientation period of one to two years, in order to provide a realistic correction-free value of gravitational effects of sun, moon and earth.

After that, the drift phase will begin which should last at least 20 years. Dr. Viktor Kudielka, OE1VKW, has presented many proposals on possible orientation and drift phases [2].

Figure 2 shows the attendant course of the perigee, height. It starts at a value of 529 km, then declines slowly and after 15 years is about 7400 km. The result is that at the beginning of the drift phase the Doppler shift results in large values at the perigee, which later on become noticeably smaller.

General Diagrams for Phase 3D

With the aid of Figures 3 and 4, all Doppler frequency shifts can be determined for optional operating frequencies. The values in the diagrams are calculated for 1 GHz. The relationship between Doppler shift and frequency is linear.

Example: Mailbox operation for Mode LS, Figure 3

- Uplink 1269 MHz: max. Doppler shift at Perigee = $31.849 \text{ kHz/GHz} * 1.269 \text{ GHz} = 40.416 \text{ kHz}$
- Downlink: 2400 MHz: max. Doppler shift at perigee = $31.849 \text{ kHz/GHz} * 2.4 \text{ GHz} = 76.438 \text{ kHz}$

Figure 4 is treated in a similar manner. It shows the Doppler shift 15 years after the beginning of the drift phase. As a result, the world appears friendlier at this time.

The hardware for this operation mode may still be on hand by some operators from the OSCAR-13 era.

Mode-S on Phase 3D (Similar to AO-13)

Quite a few operators have worked OSCAR-13 on Mode-S (Uplink 70 cm, Downlink 13 cm). The same hardware can also be used on Phase3D. Figures 5 and 6 present the Doppler shifts at the beginning of the drift phase and after 15 years. Although AO-13 did not have an

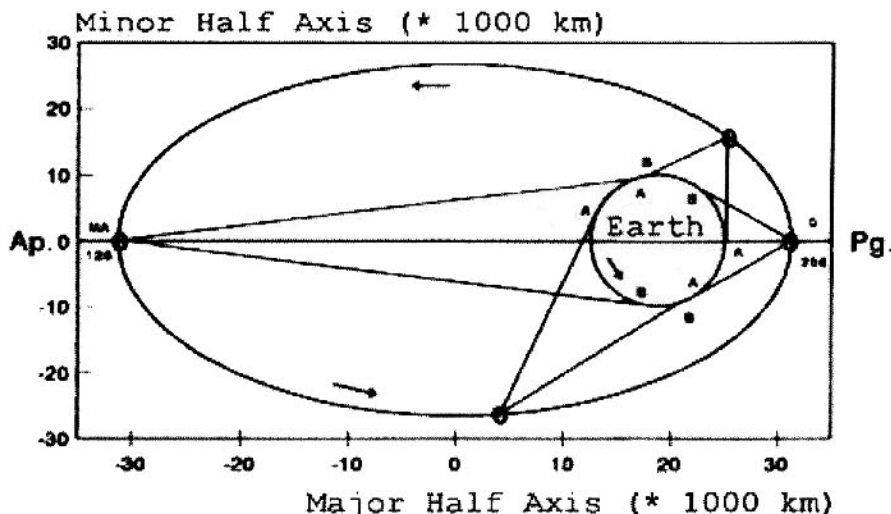


Figure 1. Basic Diagram for Calculating Phase 3D Doppler Shift.

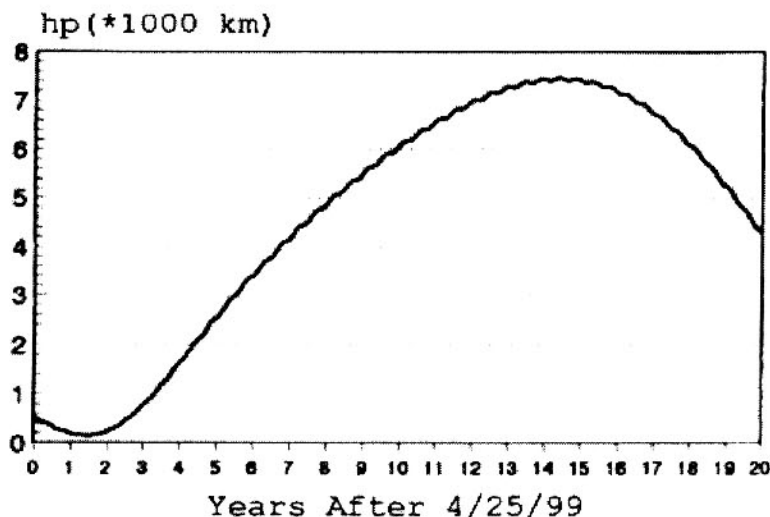


Figure 2. Phase 3D During Drift Phase, Change of Perigee.

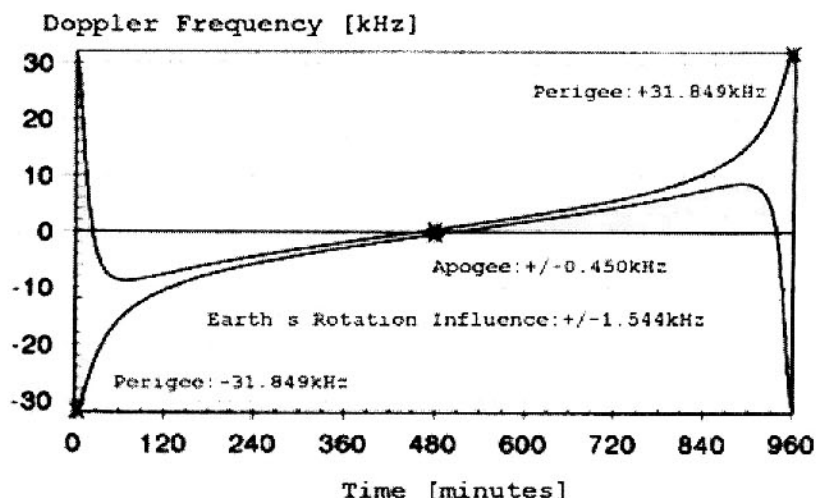


Figure 3. Maximum Phase 3D Doppler Shift at the Beginning of Drift Phase, $f = 1$ GHz.

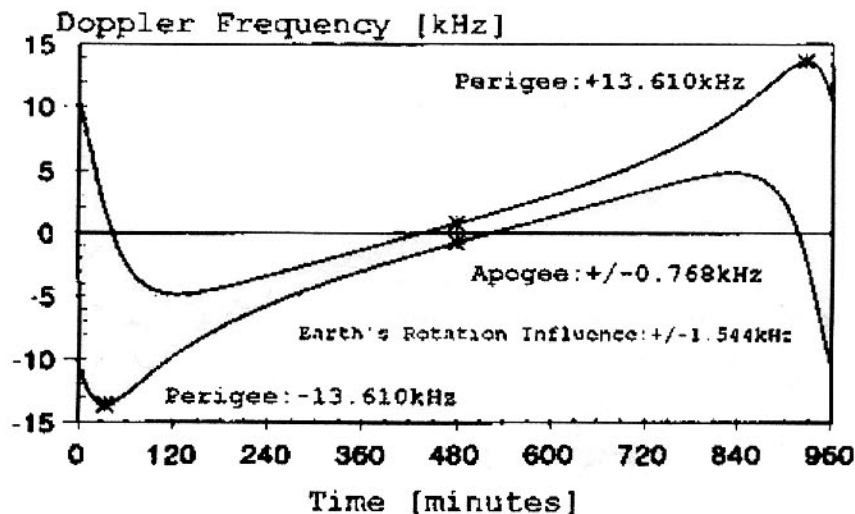


Figure 4. Maximum Doppler Shift 15 Years After Beginning of Drift Phase, $f = 1$ GHz.

inverting operational system on Mode-S, it has been presumed in these computations.

Figure 5 shows that the range of the Doppler compensation has to be nearly ± 63 kHz. During the apogee at the equator it is somewhat more than ± 2 kHz. Both figures take into account, as mentioned previously, that the satellite circles in the direction of the earth's rotation.

Control Possibilities

The maximum and minimum Doppler shift values can be accommodated by a normal satellite computer program which includes Doppler shift. One selects an inclination of 90 degrees and looks up the apogee in the orbital plane of the north or south pole at an elevation of 0 degrees (accordingly fitting the appropriate perigee angle). To get the maximum value use the value at one of the poles, select the perigee angle so that the perigee is at an elevation of 90 degrees, and read out the shifts at AOS and LOS.

One can also select a QTH at the equator and examine the apogee, again at an angle of 0 Degrees (the assumed inclination must be 0 degrees) or, to get the maximum value, situated below the perigee, one reads out the shifts at AOS and LOS as previously. The resultant values are then smaller because of the earth's rotation than that shown in the graphics.

This control scheme results in an accuracy of better than ± 100 Hz.

Here are the allowable additional data for those who wish to control with a satellite computer program: Orbital period 960 minutes MA 256, eccentricity for Figures 3 and 5: 0.7855 and Figures 4 and 6: 0.5726.

Impact of the Calculations

The evaluated orbit belongs to the past because of the delay in the launch, even if the date of the beginning of the drift phase is in the future. For planning the station there are no changes, since all of OK1VKW's proposed drift phases have a similar result, as Figure 2 shows.

Using Figures 3 and 4 a scheme for predicting automatic Doppler shift compensation ranges is very easy. It is simply necessary to multiply the maximum frequency shift by the frequency in GHz.

There is already operational experience based on AO-10 and AO-13 for satellite

operation up to 2400 MHz on hand. This operation will now be more closely examined (see Table 1).

All analog modes take into account an inverting of the signal. Using operational modes A, B, and J there will be no problems in establishing the compensation ranges. Beginning at 2400 MHz it can become critical. If one uses a 2 meter transverter and compensates the Doppler shift, the band limits can be reached. For the first three operating modes manual shift compensation is imaginable. Above 1296 MHz two hands would be inadequate to operate the station.

At 24 GHz one has the imposing value of nearly 765 kHz. After 15 drift years it is still about 327 kHz. If these values run into the technical limits of the station at hand, there is always the alternative to wait until the satellite has left perigee. At apogee the Doppler shifts at 24 GHz are less than 20 kHz. It is simply because of the available antennas on Phase 3D and its limited illumination of the earth at perigee that one can hardly expect the high frequency microwave bands (above 5.6 GHz) to be used at the perigee.

Summary

We should view the anticipated, large Doppler frequency shifts as a technical challenge. Many satellite enthusiasts have experienced the fascination of Mode-S and LS on OSCAR-13. Additionally, since our new satellite will have additional transponders, we will be offered an extensive operational field of activity. This presentation should serve as an inspiration for the expansion of ones own station while also being a preview of operation via Phase 3D.

Sources

[1] Martin Davidoff, K2UBC: *The Radio Amateur's Satellite Handbook*, 1998 Edition.

[2] Viktor Kudielka, OK1VKW: *Phase 3D Launch Sequence Study, Part IV*. ■

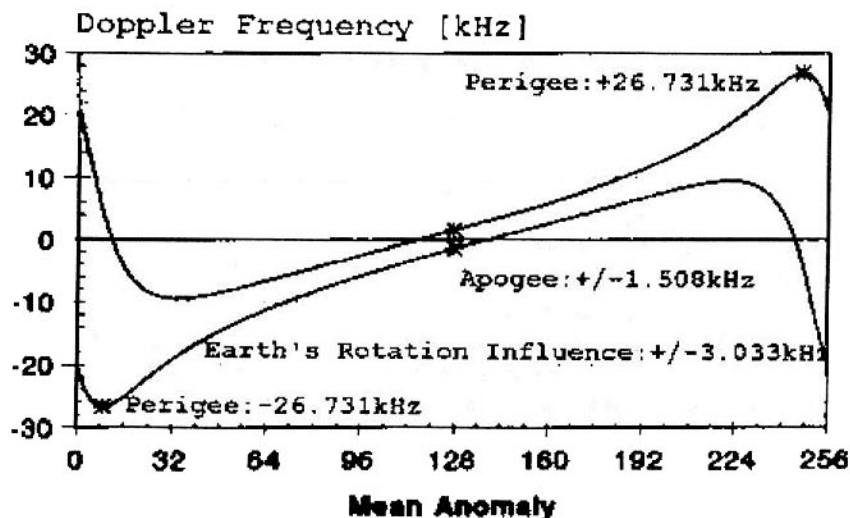


Figure 5. Maximum Phase 3D Doppler Shift, Mode-S at the Beginning of Drift Phase.

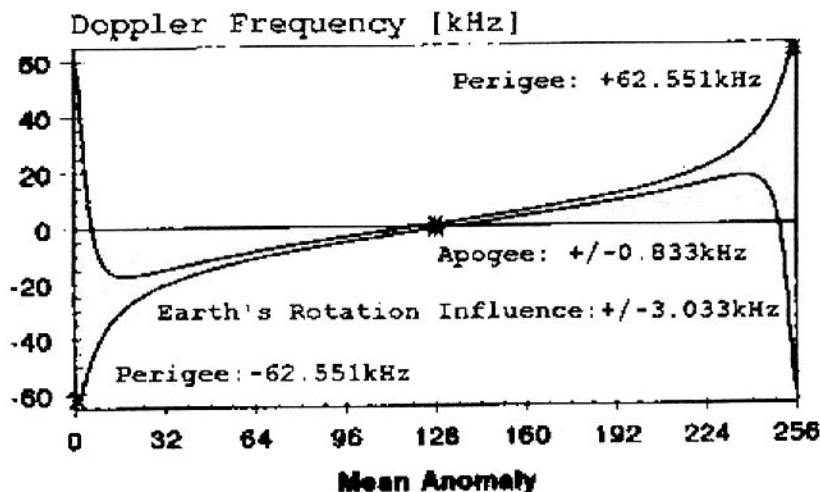


Figure 6. Phase 3D Doppler Shift, Mode S, 15 Years After Beginning of Drift Phase.

Table 1. Phase 3D Doppler Shifts by Satellite Modes

Mode	Uplink/Downlink (MHz)	Maximum Shift (Digital)	Maximum Shift (Analog)
A	145/29	4.618/0.924 kHz	3.694 kHz
B	436/145	13/886/4.618 kHz	9.268 kHz
J	145/436	4.618/13.886 kHz	9.268 kHz
LS	1269/2400	40.416/76.438 kHz	36.022 kHz
S	436/2400	13.886/76.438 KHz	62.552 kHz

Field Ops Update: Information Resources

Barry A. Baines, WD4ASW (wd4asw@amsat.org)

With summer over and the AMSAT Symposium coming up in October, we once again refocus our sights on amateur satellites. Fall also means attending club meetings and hamfests. AMSAT members are always being asked a variety of questions pertaining to our satellite hobby. Given the wide variety of interests within the satellite community, it is difficult to keep up with all facets of our hobby. Area Coordinators in particular may be approached by people interested in getting started or be asked questions which they do not have personal experience.

When I'm asked about where to find information, I always mention these sources:

General Information

AMSAT has the following listings available from the AMSAT office:

- *The AMSAT Satellite Resource Guide* updated by Mike Seguin, N1JEZ provides a significantly more complete listing of materials than what I mention in this article. Over eight pages long, the Resource Guide is offered to new members and can be obtained from the AMSAT-NA office.
- *AMSAT Information Services Worldwide* which was recently updated by Andy Reynolds, WD9IYT, provides a listings of HF & VHF Voice Nets as well as Telephone Dial-Up BBSs which contain Satellite Information.
- *What is AMSAT?* is a brochure which describes AMSAT and includes a membership form.
- *AMSAT-NA Area Coordinators Listing* is available from the AMSAT office and includes the addresses/phone numbers of AMSAT's 153 area coordinators in the US and Canada as well as Country Representatives outside North America. This listing is continually updated and supercedes the version that appeared in the March/April 1999 *The AMSAT Journal*.

Books

AMSAT offers a number of publications that cover a variety of areas. These include:

Beginner's Publications:

- *How to Use the Amateur Radio Satellites* by Keith Baker, KB1SF provides a brief summary of each satellite, including frequencies and modes, orbital description, and an overview of how the satellite is being used.
- *Working the Easy Sats* by Gary Rogers, WA4YMZ. Gary provides an excellent overview on getting started on the RS Satellites and AO-27. Based upon his personal experience, this is an easy-to-read description on how to get a started. Note: This material is also available on the AMSAT Web Site.

Specialized Publications:

- *The Analog Satellites Operating Guide* by Gould Smith, WA4SXM provides in-depth discussions on using all of the analog satellites that were in operation as of April 1998. This includes such as AO-27, RS-12, SAREX, and MIR.
- *The AMSAT-NA Digital Satellite Guide* edited by Steve Bible, N7HPR covers all of the digital satellites in operation as of April 1998. Both 1200 PSK and 9600 DFM satellites are covered. The latest edition includes materials on installation and configuration of WISP-32.
- *The Phase 3-D Pre-flight Ground Station Planning Guide* edited by Paul Beckman, WA0RSE covers all facets of preparing a ground station for Phase 3D. An overview of the satellite is provided as well as discussion of ground station equipment, such as antennas, pre-amplifiers, and station design considerations for microwave operation.
- *Mode S: The Book* from Ed Krome, K9EK, covers all areas of 2400 MHz operations, including antennas, pre-amplifiers, and transverters.
- *Proceedings of the AMSAT Symposium* contain papers that are presented at that year's Symposium. You will find a wealth of information concerning new satellites, new applications, and new ideas for the amateur satellite program. If you can't attend a Symposium, you can still obtain copies of the Proceedings.

Other Publications

The ARRL continues to publish books of interest to the satellite operator. These include:

- *The Radio Amateur's Satellite Handbook* by Martin Davidoff, K2UBC is the 'bible' of amateur satellite operations. Martin covers all facets of satellite operations as well as provides an historical overview of the amateur satellite program. It is also available from the AMSAT office.
- *Weather Satellite Handbook* by Ralph Taggart, WB8DQT discusses all areas of receiving imagery from weather satellites. Various modes are covered, including APT and HRPT.
- *The ARRL Satellite Anthology* is a collection of articles plus materials from the AMSAT web site pertaining to our hobby.

Periodicals

- *The AMSAT Journal* edited by Russ Tillman, K5NRK is published bi-monthly and is sent to all AMSAT-NA members. Prior to *The AMSAT Journal*, AMSAT published *ORBIT*. All of these publications have provided a wealth of information over the years.
- *OSCAR Satellite Report* is a newsletter published biweekly by Harlan Technologies. Much of the material included is from information obtained from the *amsat-bb*. People not on the Internet may find this particularly useful.
- Various periodicals have satellite columns. *QST*, *CQ/VHF Magazine*, *World Radio*, *73 Magazine*, and *Monitoring Times* usually have something of interest to the satellite enthusiast.

Internet Messaging

AMSAT offers a variety of e-mail services in support of information distribution. Check the AMSAT web site for particulars as well as instructions on how to subscribe to these services.

- *ANS* is the AMSAT News Service. This is the official 'newslines' of AMSAT and contains timely information pertaining to AMSAT activities, satellite status, and related areas of interest. In-

dividuals with an Internet e-mail address can subscribe and have ANS forwarded to their e-mail address automatically. Various packet bulletin boards and bbs sites also have ANS available.

- **KEPS** provides weekly Keplerian data of all orbiting amateur satellites, weather satellites, and other objects of interest. Like ANS, KEPS is often available on various PBBS and bbs systems as well.
- **AMSAT-BB** is the AMSAT 'Bulletin Board.' Messages sent to amsat-bb@amsat.org will automatically be forwarded to all subscribers. Anyone can send material. It is a 'freewheeling' mechanism available for anyone interested in amateur satellites. Users ask questions, express opinions, and exchange ideas. Recipients can expect to receive a lot of e-mail, particularly if a subject generates an exchange of e-mail.
- **SAREX** is a specialized discussion area pertaining to SAREX (Space Amateur

Radio Experiment) and ARISS (Amateur Radio on the International Space Station).

Web Sites

- www.amsat.org is the AMSAT web site and is a 'gold mine' of materials! You'll find information on getting started on satellites, particulars on the various satellites currently in orbit, freeware and shareware, Keplerian data, and information on AMSAT's electronic mail services. There are also links available to other sites of interest. Paul Williamson, KB5MU, continues to upgrade the web site, so check it periodically for new features and information.
- www.tapr.org is the Tucson Amateur Packet Radio Corp. web site. You will find a variety of information available that is of interest to satellite operators including APRS, digital satellites, and related equipment (such as devices to control your rotors).

- www.arrl.org is the American Radio Relay League web site.
- www.magicnet.net/phase3d/ is the Phase 3D Integration Lab web site. Photos are updated periodically to show progress on Amateur Radio's largest satellite.

Take the time to check out these electronic resources. The Internet has certainly made it possible for individuals to seek out an almost overwhelming amount of material.

Bottom line is that satellite operators can take full advantage of a wide range of information resources. Should someone approach you about seeking information on getting started or finding additional information, take the time to share this list with him or her as well as checkout the *Resource Guide* that I mentioned earlier in this article. ■

Donating to AMSAT

Since 1969 AMSAT has worked hard to provide Amateur Radio satellites to all licensed operators. AMSAT-OSCAR 6 was launched in 1972 and was followed by AO-7, AO-8, AMSAT P3A, AO-10, AO-13, AO-16 and soon Phase 3D. Without your help, we could not have accomplished this. Our challenge now is to continue our work. Again, you can help. No matter what your income, you can almost always lower your income taxes through charitable giving. If you itemize your deductions, a gift can significantly reduce your taxes. You may wish to consider one of the following:

- **Cash Gifts** - Simply write AMSAT a check or charge your gift on VISA or MasterCard by calling 301-589-6062.
- **Gift of Life Insurance** - When you designate AMSAT as both the owner and beneficiary of a life insurance policy, you can receive a significant charitable deduction
- **Gifts of Stock** - There are two advantages when you contribute stocks to AMSAT. You can avoid paying capital gains taxes on the appreciated value of your stock and you also receive an income tax deduction for the full fair market value at the time of your gift.
- **Wills and Bequests** - Adding a codicil to your will naming AMSAT as a beneficiary may be a good approach to estate planning for you.

We encourage you to consult with your financial advisor for details on your particular tax situation.

Please remember, a gift to AMSAT is tax deductible and helps to ensure our continued existence.

Many thanks for your generous support,

Martha Saragovitz

Corporate Secretary

1999 AMSAT Field Day Competition Results

Andy MacAllister W5ACM

The 1999 AMSAT Field Day Competition was held in conjunction with the yearly American Radio Relay League Field Day in June. Rules for the AMSAT activity were similar to those posted by the ARRL, but with a few key exceptions. While the ARRL rules lump all satellite activity in one category, the AMSAT rules differentiate activity via different hamsats as separate bands. The AMSAT rules also provide bonus multipliers for digital satellite downloads and uploads of Field Day greeting messages.

The 1999 competition was very active. Submissions were down this year, as were the scores. Every available Amateur Radio satellite had Field Day participants in pursuit of contacts. Several DX stations joined in the activity. Three sent in reports this year

including ZS6BMN, OZ7SAT and XE2YVW. DX stations are encouraged to participate in the AMSAT Field Day activity.

AMSAT-OSCAR-10 was available this year, but conditions via this veteran hamsat were not optimum, as they were in 1998. The low-earth-orbit (LEO) hamsats carried the load. The loss of KITSAT OSCAR-23 had the most significant negative effect on scores. KO-23 will be missed.

The entry sheet was not modified this year and the rules were easily understood by most of the stations that submitted entries. As a reminder, the only digisat message downloads that count for Field Day are those that are addressed to ALL and were uplinked

during Field Day as Field Day greeting messages.

Download listings and analog contact dupe sheets were required from only a few top-scoring stations this year. Most stations that had high scores sent in their detailed QSO data without being asked. Several spread sheets were submitted via e-mail and checked for errors and inconsistencies. If you have a high score next year, please keep good logs and dupe sheets.

Many thanks to all of you that operated in this year's event. It was a great opportunity to show other Field Day participants how easy and exciting satellites can be. It was also a chance for some competition on the birds and an occasion to test hamsat radio gear and antennas in emergency conditions.

1999 AMSAT Field Day Competition Results

Place	Call	Points	Class	Group Name
1	K4BFT	256	5A	Huntsville Amateur Radio Club
2	K8AYZ	253	3A	L'Anse Creuse Amateur Radio Club
3	NX2Q	195	2A	N2HUQ, W2OZU, NX2Q and NG2N
4	AA4MD	182	1D	Tampa Children's Hospital - Kid's Space
5	W5IU	160	4A	Lockheed Martin Amateur Radio Club
6	N7SFI	153	1D	Randy Kohlwey
7	K4RS	134	2A	Fort Pierce Amateur Radio Club
8	OZ7SAT	132	2D	AMSAT-OZ
9	W2LV	127	3A	Sussex County Amateur Radio Club
10	ZS6BMN	120	1D	Jan Hattingh
11	W1MOO	119	5A	The Udder Club
12	W1BOS	117	3A	Boston Amateur Radio Club
13	K5DX	115	4E	AMSAT-Houston & the Texas DX Society
14	W9LO	114	4A	The Ozaukee Radio Club
15	WA0VTU	90	2A	Pike's Peak & Mountain ARC's
16	W3BN	52	3A	Reading Radio Club
17	K5OE	31	1D	Gerald R. Brown
18	KK5DO	28	1D	Bruce Paige
19	AL7LE	21	2A	Moose Horn Amateur Radio Club
20	N6AS	20	1D	Phil Crosno
20	WS8B	20	4A	XWARN
21	WA5VKS	18	1D	Dick Raitt
22	XE2YVW	9	1E	Alvaro De Leon
23	K6HAI	3	4A	North Shores Amateur Radio Club
24	W1CWA	1	3A	Bloomfield Amateur Radio Club

Per the AMSAT Field Day announcement, the first-place portable station using emergency power will receive a plaque at the AMSAT meeting in San Diego, California. Second and third place entries will receive certificates. The first-place home station running emergency power will also receive a certificate.

No rule changes are expected for the 2000 AMSAT Field Day event at this time. There have been Field Day rule discussions via amsat-bb on the Internet, and I have received some ideas for rule changes through the mail. What do you think? Please send any comments to Andy MacAllister W5ACM, AMSAT VP User Services, 14714 Knights Way Drive, Houston, TX 77083-5640.

Tim Cunningham N8DEU for K4BFT: We had a great contact with R0MIR while testing our equipment about 30 minutes before Field Day began. Noise problems were big this year. The generator caused 10-meter reception difficulties, the laptop computer interfered with 2-meter reception, and then later the TNC used for digital contacts caused further 10-meter problems. We had a lot of help though. Participants included Christie KD4QIO, Dieter KX4Y, John N5DF, George K4TFJ, Greg KE4ROL and Bruce W4BHC. We also had nice visits by a local Boy Scout troop and some other folks that stopped by to chat and operate throughout the exercise.

Tom Mathison WU8C for K8AYZ:

Conditions were not nearly as good as last year. Murphy was against me. I started using my GPS to set the clock and couldn't understand why I couldn't hear UO-22 and KO-25. I had forgotten about the Daylight Time correction and was an hour off. AO-10 was excellent and provided some good DX. Looking forward to next year -hopefully with a new bird or two?!?!?

Albert Tencza for NX2Q:

Ham radio's heritage of keen monitoring surfaced again at our High Point State Park, NJ contest site. During the Sunday-morning lull, Phil N2HUC noticed an AO-27 low-elevation pass (3 deg. max.) that was not in the pre-printed listings. Phil got on it and logged several stations, including one that was maritime mobile. We were getting some hot conditions on Sunday morning, including the weather. We turned on the AC to get cool, and got a bonus... spraying condensation.

Jim Huhta for AA4MD: The digital birds are awesome!

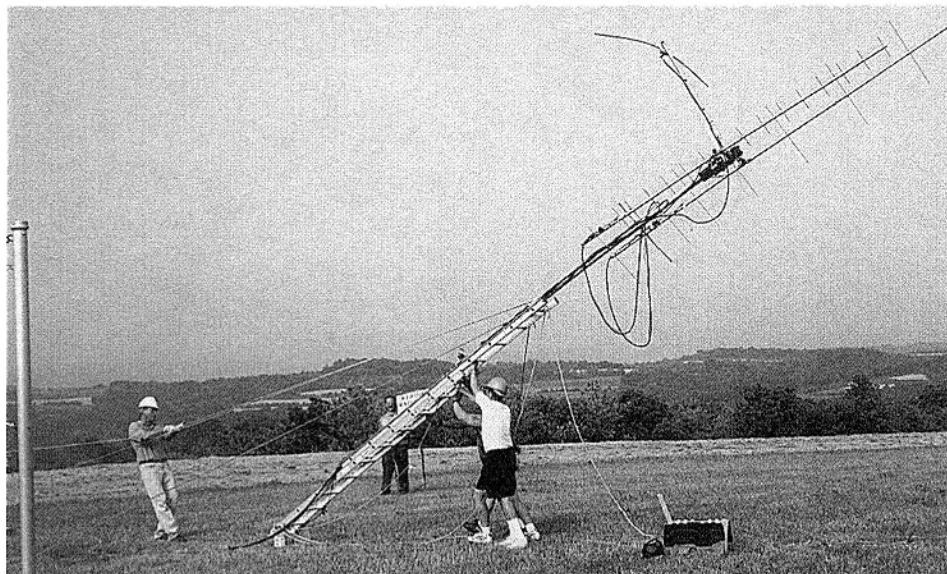
Keith Pugh for W5IU: Slow start - GREAT finish! Ray WA5QGD and Gary KD5DAY did most of the work this year.

Roger Snyder for K4RS: Once again the Fort Pierce (Florida) ARC had a fantastic Field Day. We returned to the campus of the Indian River Community College for a second year. I don't believe we could find a better Field Day location. We had few technical problems, but Mother Nature was back with a vengeance! Severe thunderstorms with heavy rain and lots of lightning were rampant. Next year we may need to add SCUBA gear to the list of equipment.

The loss of KO-23 and the fact that several newly launched birds were not open for general use caused our point total to drop from last year. We experimented with new rig control software and found analog operation to be much more enjoyable. With all the stations trying to find their downlinks, it was nice to know that our station was not adding to the QRM.

We had lots of visitors to the satellite station. Everyone had a good time and we all learned something to improve our emergency-preparedness skills. We are already making plans for next year.

Bent Bagger OZ6BL for OZ7SAT: The orbit for AO-10 was very good this year better



The W3BN Reading Radio Club, Pennsylvania raising their satellite antennas. The aluminum ladder base support is staked to the ground with a 36" steel stake in the center. The entire assembly can be rotated to align azimuth after erection when an additional stake holds the assembly in position.

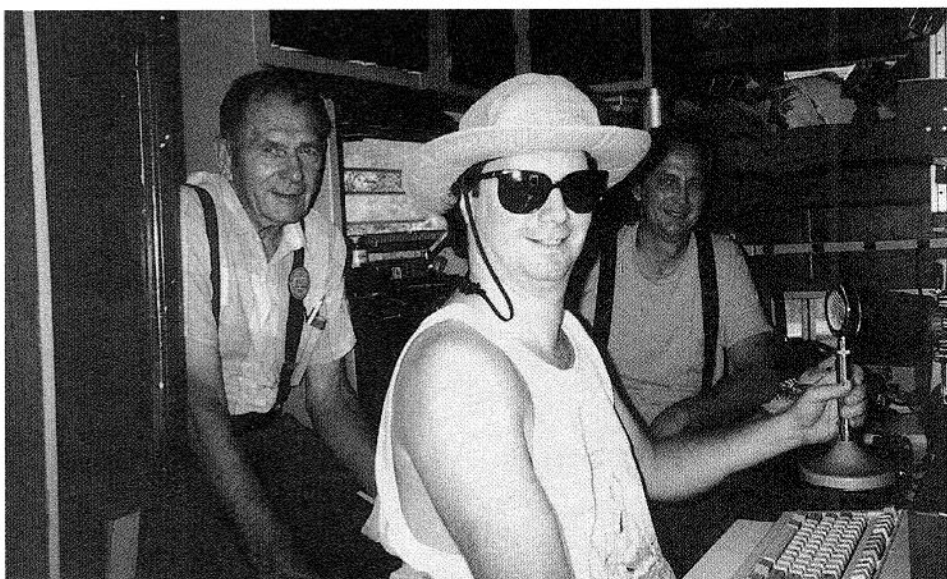
than 1998. We made most of our analog contacts with east-coast US stations this time. On the digital front we had to do without both LO-19 and KO-23, so the score was not as high. It was a pleasure to do the log this year, as there were few if any duplicates.

John Santillo N2HMM for W2LV:

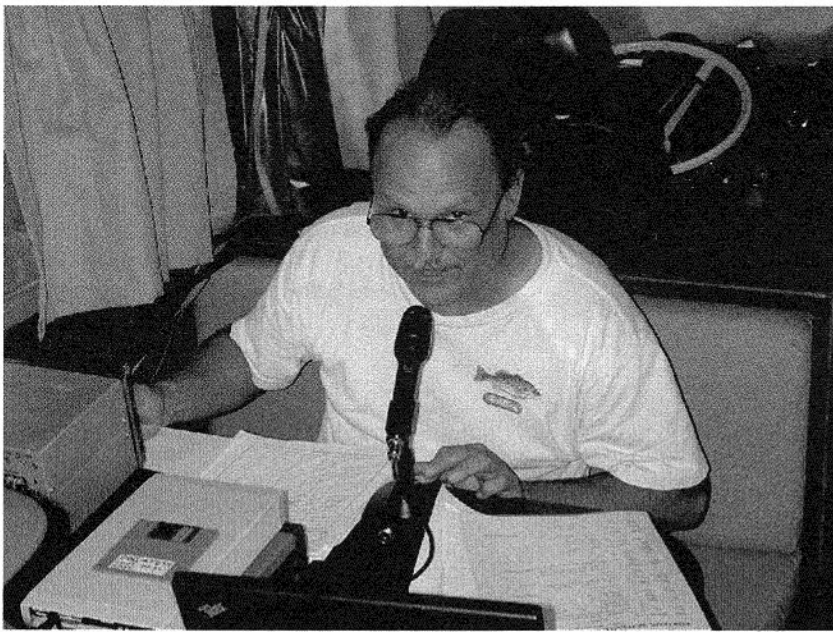
HEAT. It was the hottest Field Day that anyone could remember. To us *Yanks*, operating W2LV (3A NNJ), temperatures in the mid 90's provided an additional challenge to the Field Day exercise. Even with some positions left without an operator for some periods due to

the heat, our total club score matched 1998 levels, and as of this writing, the Sussex County Amateur Radio Club was in first place by a slim 400 points.

For the satellites, AO-10 was really hopping, especially early on Sunday with excellent signals and good DX. The RS birds did well, but AO-27 was a real *zoo*. Everyone on the bird seemed to be trying to overpower everyone else to gain the FM capture effect. FO-20 and FO-29 provided the strongest downlink signals. I had as many contacts on the Fuji's as via AO-10. We even got some



NX2Q Field Day Station at High Point State Park, New Jersey. Left to right, Stan W2OZU, Phil N2HUC; and Al, NX2Q.



K5DX Field Day Station, Texas. AMSAT Awards Manager, Mike Scarcella, WA5TWT makes another AO-10 contact.

air time on a local TV station. We'll be back next year!

Jan Hattingh for ZS6BMN: It is a pity that there were two less digital satellites this year, but the activity remained fairly high on those remaining. This year I was careful to only upload one message per digisat. All in all, it was great fun, as usual!

Mike Seguin N1JEZ for W1MOO (The Udder Club): We had planned to operate all birds again this year, but had a last minute change and had to drop digisats. As promised by the weatherman, we were treated to a heat wave all weekend. About two hours into Field

Day the 5 kW generator gave out. Later, even the back-up generator gave out due to the heat. The HF station folks donated their back-up, and we used it for the remainder of the event.

Field Day Rule Number 1: Check the fuel in the generator when it dies. The primary generator had simply run out of gas. The high point of the event was working 9A1CAL on AO-10. It was also great to work KP4ES. The low points were the heat and the generator debacle. As one one of our satellite guys said, "Well, we've frozen at -35F in February operating W1B, and now we've roasted on Field Day at +96F, so we know what a TV

dinner feels like!" We hope to work you all next year! Moo

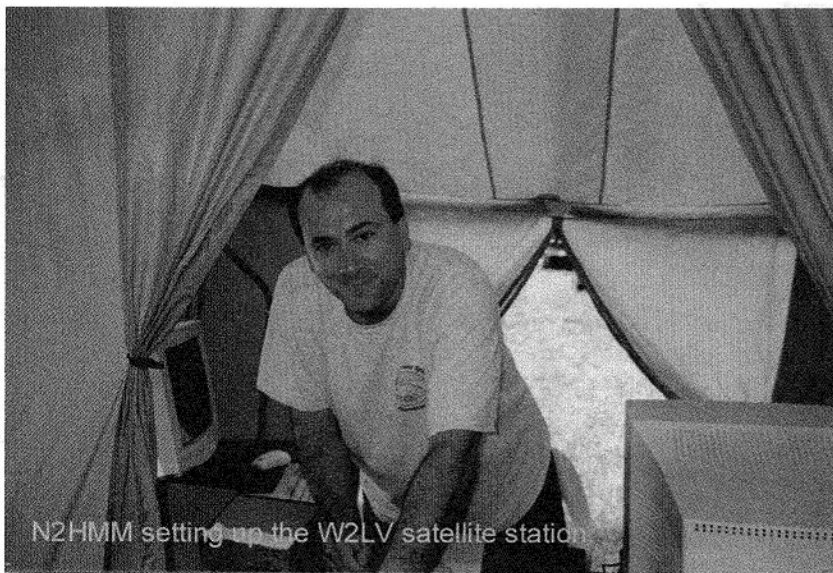
Rick Muese N1HID for W1BOS: We had a lot of fun this year with the Boston Amateur Radio Club. We operated at the Larz Anderson Park in Brookline, MA along with myself and Bill KD1NX. We set up a complete satellite station and did well on KO-25 and UO-22. We heard the analog satellites, but did not make any contacts. It was all digital this time. Too bad KO-23 wasn't working.

Andy MacAllister W5ACM for K5DX: When we got the Texas DX Society Field Day site, there was no one there! Weather conditions and a new road for a nearby drilling rig had made access to the usual spot impossible. The DX Society had decided to work from the permanent *shack* (a 3-bedroom house owned by the group) using emergency power. We set up the satellite station in a nearby mobile home and worked the event as "4E." Once again we only *listened* to the digital birds without transmitting, but still managed to add some valuable digisat points by collecting FD messages from KO-25. The analog satellites provided the bulk of our score, and were a lot of fun. At the end of Field Day, Tim KD5DTH "launched" a dual-band HT on a kite set for crossband repeat. We had some fun with that as the event wound down. More next year!

Gary Bargholz N9UUR for W9LO: What Wisconsin Nine Lousy Operator learned at the 1999 Field Day:

- A 15-Amp power supply will not put out enough current to run 100 Watts out on UHF.
- The six-meter station (900 Watts ERP) in your tent is OK, until they swing their beam directly at your two-meter satellite downlink antenna.
- Don't put the fact that you have home-made beer in your digisat FD message... Everybody (worldwide) will want some.

We had a wonderful Field Day experience this year. Many visitors came through the satellite station. More was said off the air than on. Digisat efforts were much better with WISP and a *trackbox*. The digital system was almost autonomous, giving us time to explain the system to onlookers, rather than tediously run it.



John Santillo, N2HMM setting up the W2LV satellite station in Northern New Jersey.

The highlight of Field Day this year was working Jens HB9JOI via AO-10. I had the new Kenwood VC-H1 SSTV microphone along. Jens sent a new *Mir* picture to us and we sent Field Day pictures to him. Everyone was excited. Thanks Jens! What a demo! So what if we lost 20 minutes of prime operating time on AO-10. We sure had FUN! See you next year! I'll send you a picture of my Beer.

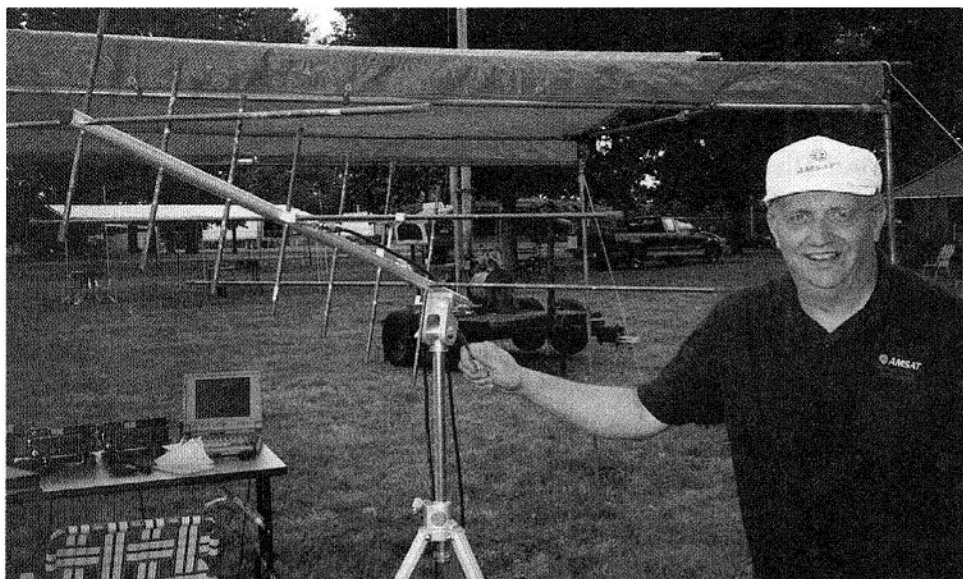
Tom McDaniel N0NTX for WA0VTU: Great Fun! We tried to work RS-13, but the SSB station was a little too close and 15 meters was open. My only complaint (same as last year) is that I would like to have seen more digital stations play!

Lew Hill N3WTW for W3BN: The Reading Radio Club participated in Field Day 1999 as a 3A entry using the club call W3BN. We worked HF, digital, VHF and satellite from a site at Blue Marsh Lake, a U.S. Army Corps of Engineers water resource development project (*Editor's Note: Good on you! Let's give them another 10 points for their innovative location!*). A 23-foot camper provided power and shelter for the VHF and satellite stations. We had a great time working AO-10. Our last contact was when the satellite was 39,500 km out with HA2RD in Hungary. That was quite a thrill! Our operation was featured in the Reading Eagle on the front page of the second section. Great publicity.

Gerald Brown for K5OE: AO-10 was my best bird, but I also did well on the last pass of FO-29 when most of the *big guns* had already shut down. FO-20 on Saturday night sounded more like AO-27 and I couldn't even find my own uplink. It was much better on Sunday morning. It was a lot of fun and a good test of emergency communications. I just hope an emergency never happens on a contest weekend!

Bruce Paige for KK5DO: As expected, AO-27 was swamped with attempted contacts. Even the last pass of Field Day, that ended after 1800Z was packed. I managed to work KD6IRE, W5IU and XE1MEX on that one. AO-10 was very good. I made some nice contacts even when the satellite was over 39,000 km out.

Ed Cole AL7EB for AL7LE: I had a really nice Field Day operation using a borrowed van from the Kenai Peninsula Borough Office of Emergency Services. The antennas came from Mike West WL7BQM (Alaska AMSAT AC) and the radio belonged to Larry



AMSAT-NA President Keith Baker, KB1SF showing off his Arrow antenna mounted to a photo tripod that was used to snag a number of CW contacts via AO-10 at the WS8B Field Day Station, Xenia, Ohio.

Halvarson KL7FG. I brought a 50 Watt amp that we mounted at the antenna. This was the second year for our club to chase satellites and we enjoyed it.

Phil Crosno for N6AS: This year I used an eight-foot wooden stepladder as an antenna mount in the middle of the driveway. It worked!

Keith Baker KB1SF for WS8B: We used an Arrow antenna on a tripod and about 60 Watts of uplink power for AO-10 work this year. We ran 10 Watts for the Fuji's and had a lot of fun!

Dick Raitt for WA5VKS: This was my first time to enter this contest. This was also the first time for my new satellite antennas...a good test. RS-13 had too much 15-meter uplink interference. I couldn't tell who was actually trying to work through the satellite. I'm looking forward to participating again next year.

Alvaro De Leon for XE2YVW: This was my first Field Day via satellite. It was amazing! Thanks to all for a great time!

Dave Guimont WB6LLO for K6HAI: C U in San Diego!!! ■



Bent, OZ6BL and Lars, OZ1FFR enjoy a refreshment break to discuss tactics for the remainder of Field Day at their Denmark station.

Results of the AMSAT-NA Board of Directors Election

Martha Saragovitz, AMSAT-NA Corporate Secretary has announced the results of the recent AMSAT-NA Board of Directors election. The following ballots were cast for:

Dick Daniels, W4PUJ,1118*
Bill Tynan, W3XO,1049*
Robin Haighton, VE3FRH, ...1005*
Barry Baines, WD4ASW,993*
Mike Gilchrist, KF4FDJ,569#

As a result of this election, Dick Daniels, Bill Tynan, Robin Haighton and Barry Baines will begin service on the Board of Directors at the next meeting scheduled to be held in San Diego on 10-11 October 1999. Mike Gilchrist will serve as the alternate until the next election.

Phase 3D Successfully Completes Vibration Testing

Lou MacFadin, W5DID, tells ANS that vibration testing of the Phase 3D satellite has been completed successfully. "This is a major milestone for the spacecraft," said W5DID. "The satellite did very well under rigorous environmental tests." The Phase 3D vibration tests were conducted at the Goddard Spaceflight Center in Greenbelt, Maryland. McFadin also thanks the numerous AMSAT members in the Washington, DC area for their continual assistance during the tests.

W5DID reports that after the vibration tests, Phase 3D successfully returned to the Phase 3D Integration Laboratory in Orlando, Florida. The next step is to verify that all Phase 3D systems are functioning normally following the return trip.

MICROSAT Class FM Transponder in Elliptical and Low Earth Orbits

Recently on AMSAT-BB, there has been considerable and productive discussion on the need and feasibility to develop

easy-to-operate low earth orbit FM satellites. As a result, Peter Guelzow, DB2OS posted a reprint of an e-mail post by Walt Daniel, KE3HP that was written five years ago. The following presents KE3HP's thoughts on the technical design challenges that must be met to successfully operate low earth orbit FM transponders:

Low Earth Orbit

Let's say that a small, microsat-class satellite with a Mode B FM transponder is launched into a polar low Earth orbit. The satellite is about 9 inches (23 cm) on a side, so the area of one face is 0.0529 m^2 . Assuming that all of that area is covered with solar cells (which isn't the case) and that one side faces the Sun, the power available when in sunlight is:

$$\bullet \text{ power} = 1353 \text{ W/m}^2 * 0.0529 \text{ m}^2 * 0.10 = 7 \text{ W}$$

Where 1353 W/m^2 is the solar flux and 0.10 represents the 10% efficiency of silicon solar cells.

Assume that the orbit is 600 km circular (actually a bit low). The period is about 100 minutes and maximum eclipse time is about 36 minutes. The power budget in sunlight would be.

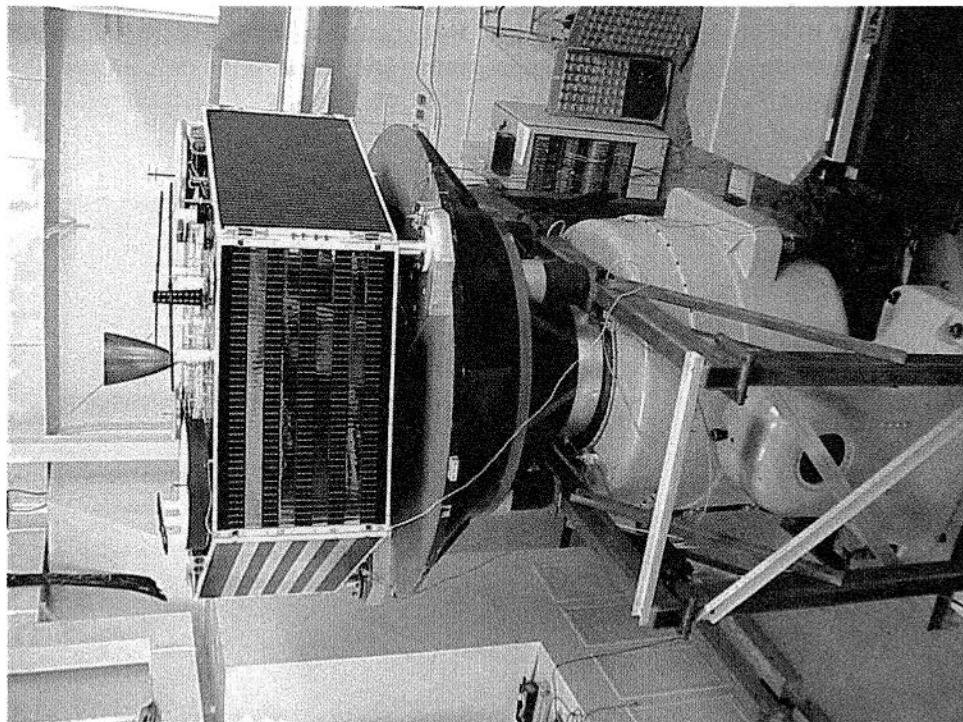
- 3 W to spacecraft systems (computer, receiver, etc.)
- 3 W to charge battery (battery and charger not perfectly efficient)
- 1 W to transmitter

So, the RF output would be 0.5 W (-3 dBW) with a transmitter efficiency of 50%. The satellite is passively stabilized, so no transmitter antenna gain is present. The system is designed for reception on an HT, so no receiver antenna gain is present.

If the satellite is 20 degrees above the user's horizon, the slant range is 1400 km. With a wavelength of 2.05 meters (146 MHz), the path loss is:

$$\bullet \text{ PL} = 10 \log(4 * \pi * 1.4\text{E}6 \text{ m} / 2.05 \text{ m})^2 = 139 \text{ dB}$$

An HT (especially with a rubber duck antenna) is not a very sensitive receiver, so I'll assume a system noise temperature of 1000 K. [Does anybody have a better estimate?] The noise power density is:



Ready to rock and roll, Phase 3D sits on the vibration test table at the Goddard Spaceflight Center, Maryland.

- $N = 10 \log(k * T_s) = -199 \text{ dBW/Hz}$

and the FM receiver bandwidth is 15 kHz (42 dB-Hz).

The link equation for the downlink is:

- xmtr power -3 dBw
- xmtr ant gain 0 dB
- path loss -139 dB
- rcvr ant gain 0 dB
- noise dens +199 dBW/Hz
- bandwidth -42 dB-Hz
- S/N 15 dB

This is barely acceptable for FM voice or 1200 bps packet. Keep in mind that I neglected polarization losses, nulls in the antenna patterns, atmospheric losses, and feedline losses.

My conclusion is that this design would not be very useful. The link is marginal and the transponder could only be used when the satellite is in sunlight. The slow tumbling of the satellite would cause the signal to fade in and out. AO-21 had a better link than this design, but then AO-21 was a small box attached to a larger satellite that provided both active stabilization and more power.

An Elliptical Orbit

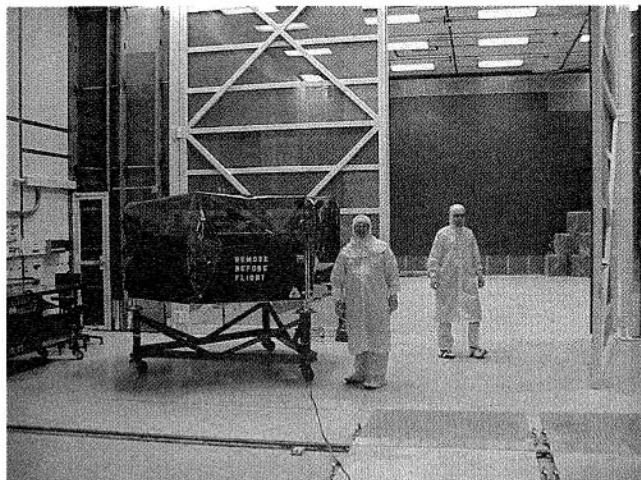
It has been suggested more than once that the large, expensive Phase 3D spacecraft be replaced with several smaller satellites. To examine this possibility, consider the FM Microsat in an elliptical orbit.

The power situation is better in that the spacecraft is in sunlight most of the time. The budget for the 7 W of power would be:

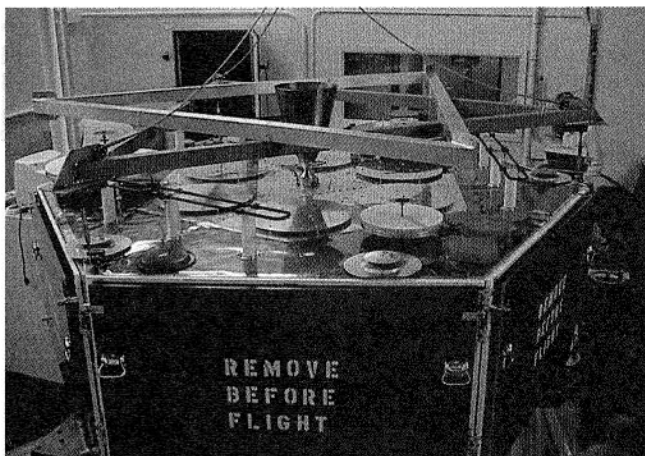
- 3 W to spacecraft systems
- trickle to charge battery
- 4 W to transmitter

So, the RF output would be 2 W (+3 dBW) with a transmitter efficiency of 50%. The satellite is only passively stabilized, so no transmitter antenna gain is present. The system is designed for reception with an HT or 2m packet antenna, so no receiver antenna gain is present.

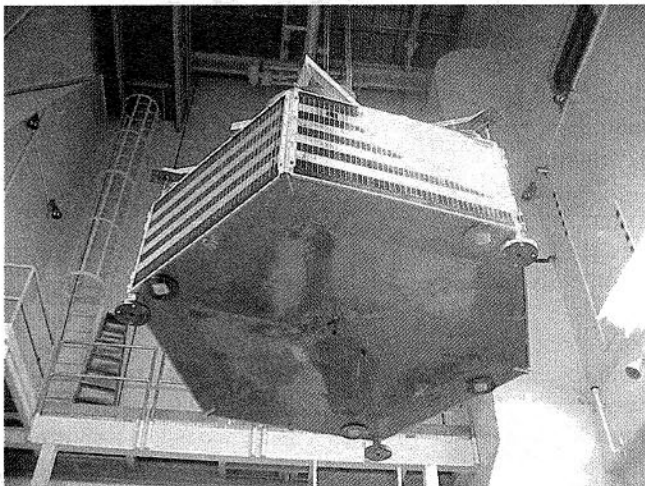
Doppler shift at perigee would make the downlink difficult to receive; apogee would be about 40,000 km. Let's compromise and



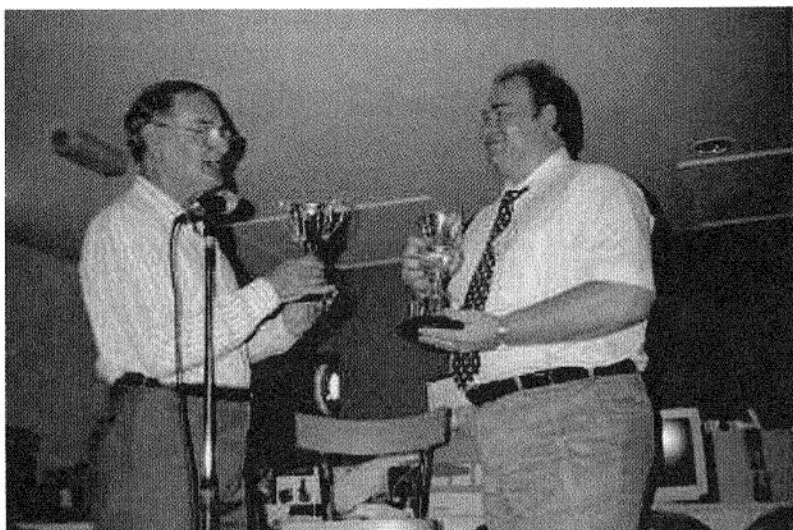
Lou McFadin, W5DID (l) and Stan Wood, WA4NFY (r) ready to wheel Phase 3D into the vibration test chamber at the Goddard Spaceflight Center, Maryland.



A hoisting bar attached to Phase 3D was used to maneuver the satellite onto the vibration stand. Note the thermal blanket insulating the antenna side of the satellite.



Lower Phase 3D onto the vibration test table. Note the exposed solar panels.



Ron Broadbent, G3AAJ (l) presenting the G3AAJ Trophy to Werner Haas, DJ5KQ on behalf of his many years of service to the Amateur Radio satellite community. Peter Guzelow (r) accepted the trophy on behalf of DJ5KQ.

make the link calculation for 20,000 km slant range. The path loss is:

- $PL = 10 \log(4 * \pi * 2.0E7 \text{ m} / 2.05 \text{ m})^2 = 162 \text{ dB}$

and I'll use the previous numbers for noise density and FM bandwidth.

The link equation for the downlink is:

- xmtr power +3 dBw
- xmtr ant gain 0 dB
- path loss -162 dB
- rcvr ant gain 0 dB
- noise dens +199 dBW/Hz
- bandwidth -42 dB-Hz
- S/N -2 dB

Once again, I've neglected polarization losses, nulls in the antenna patterns, atmospheric losses, and feedline losses. This signal is buried in the noise; I believe that FM requires S/N of more than 10 dB for acceptable performance. My conclusion is Phase 3D cannot be replaced with small, unstabilized FM satellites.

What could be done to improve the link? If the satellite were stabilized, some transmitter antenna gain would be possible. The user on the ground would also need an antenna with gain for his or her receiver. The user would need a preamp and a more sensitive receiver to get the noise power density down. Finally, the modulation would have to be CW (a few hundred Hz), SSB (3 kHz), and narrow-bandwidth digital modes. Wait a

minute...I've just described a typical AO-13 set up!

Phase 3D offers three advantages with its three-axis stabilization: more power for the transmitters, higher transmitter antenna gain, and lower pointing losses. (Anybody who has tried to work AO-13 lately knows all about pointing losses.) With Phase 3D doing more in space, life will be easier for users on the ground. While an HT won't let you work Phase 3D, you might be able to use a small Yagi antenna pointed at the same spot in the sky instead of large Yagis on rotators.

Launch Opportunities

One of the major factors that drove the Phase 3D design was the launch opportunity that was generously offered by Arianespace. The Ariane 5 is going to geostationary transfer orbit, so the only choice possible is a high elliptical orbit. High orbit dictates stabilization so that more power, higher gain, and better pointing are possible. My conclusion is that the Phase 3D design is the

right choice (likely the only choice) for this launch opportunity.

There don't seem to be many low Earth launch opportunities these days. The success of the Microsats and the University of Surrey spacecraft caused the launch companies to start selling their secondary payload space. Even the days of riding piggyback on another satellite (e.g., RS-10, AO-21) seem to be over. RS-15 finally got into orbit, but as a small, free-flying satellite with low power, high altitude, and no stabilization — its downlink is weak and the fading (due to tumbling) makes the transponder difficult to use. There aren't too many high-power amateur radio payloads going into orbit in the near future. In the end, the AMSAT societies have to use whatever launch opportunities become available.

Thanks for your time and sorry about the length of this...73, Walt KE3HP

Results of the AMSAT-UK Colloquium

About 80 people from 18 countries and 5 continents got together in Surrey, England on



Chris Jackson, ZL2TPO of TO-31 and UO-36 fame, gave an interesting talk at the AMSAT-UK Colloquium on UO-36 gravity gradient boom.

23-25 July 1999 for the AMSAT-UK Colloquium. Program Organizer Richard Limebear, G3RWL reports on the following highlights and information obtained at the Colloquium:

- What is Phase 3D's highest frequency downlink ? Wrong, it is not 24 GHz. There is a laser on board, half a watt on 834 nM which is intended to be modulated by 400 bps data and CW (a phantom flasher?).
- SSTL's UoSat-12 (UO-36) carries a (yet to be used) gravity gradient boom. Incidentally their first mock-up of the bird was made in plywood from a local DIY store.
- Orbits can be *tuned*, if you have a small propulsion system on board, into what is called a *frozen orbit* whereby perturbations can be minimized.
- AMSAT-France has stopped work on their Maelle project so that they can concentrate their resources on other (educational) projects.
- Techsat (TM-32) may have BBS software loaded soon.

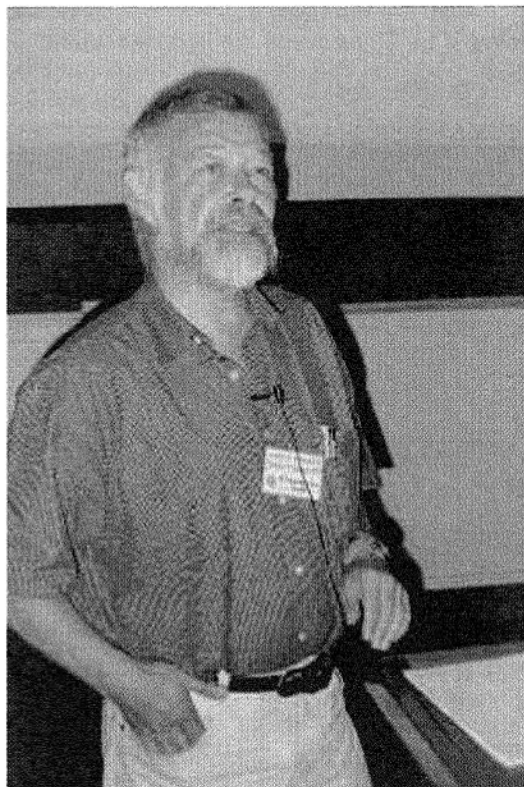
There was a good mix of speakers across the board ranging from Ph.D. papers to how to modify various pieces of equipment (e.g. for 38K4 and Drake 2880's). A small team of testers, with sophisticated test equipment reaching up into the microwave bands, did sterling service and were kept busy mainly, it seems, with Drake 2880 converters.

Beginners' sessions were, for the first time, included as a second lecture stream. These were popular on the Saturday but poorly attended on Sunday (they competed with a rocket firing). This innovation (beginners, not rockets) will be included in future Colloquia but probably only on Saturday.

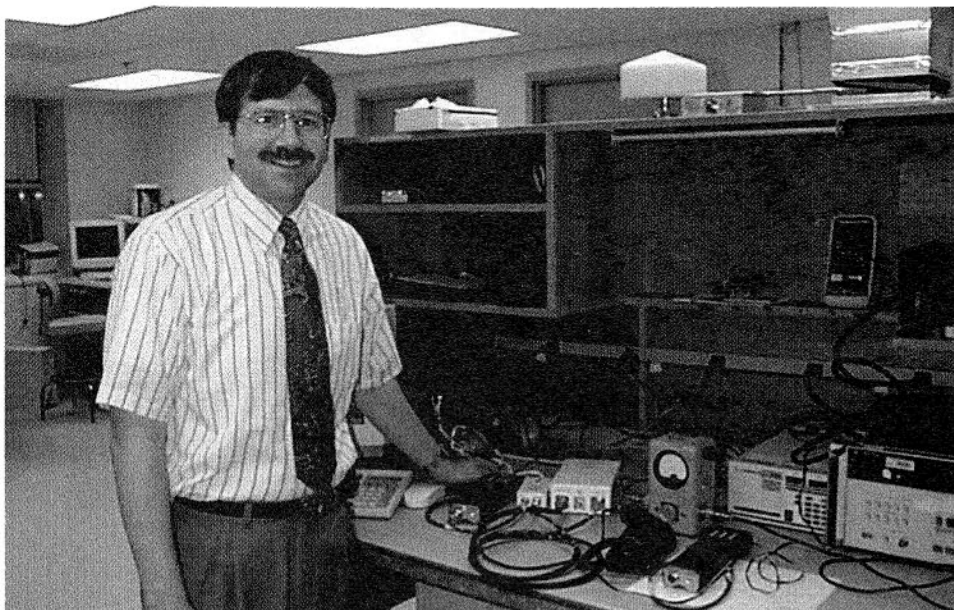
The annual Dinner and junk sale of surplus equipment was well attended. There weren't many presentations (we sell surplus rather than make speeches) but AMSAT-UK presented AMSAT-NA President Keith Baker, KB1SF with a check for US\$13,340 to cover expenses for Phase 3D's thermal blankets. Also, Ib Christoffersen, OZ1MY, presented a check on behalf of AMSAT-OZ donating US\$1,400 to the AMSAT-UK Phase 3D fund. The G3AAJ trophy was awarded to Werner Haas DJ5KQ in recognition of his many (many, many) years of service to Amateur Radio satellites. It was



OSCAR News Editor Jenny Southwell, G1LIT (I) presenting AMSAT-NA Keith Baker, KB1SF with a check for US\$ 13,340 to cover the expenses for installing a thermal blanket on Phase 3D. Please remember to thank our AMSAT-UK friends for their generous contributions when working them via Phase 3D!



Ib Christoffersen, OZ1MY, made a generous donation to the AMSAT-UK Phase 3D fund on behalf of AMSAT-OZ.



Frank Bauer, KA3HDO during testing of the ARISS equipment. Note the prototype antenna is shown on the top of the shelf to Frank's left. The pyramid-shaped structure is the L/S band antenna that is mounted on its EVA hardware.

presented to Peter Guelzow, DB2OS as Werner was unable to attend.

The final presentation of the Colloquium was a report on the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis conducted earlier this year by AMSAT-UK in response to a decrease in membership. This full report will shortly be available on AMSAT-UK's web pages (<http://www.uk.amsat.org/>) for all members

who care to comment. The Colloquium was followed by the AMSAT-UK Annual Meeting where most of the committee were re-elected and other business was conducted.

Many thanks to Richard Limebear, G3RWL for this report.



AREMIR

OE Ø MIR



After running the *Mir* QSL card collection in the last issue of *The AMSAT Journal*, Presley Smith, N5VGC sent us a QSL card from when Austrian Franz Viehbock was on *Mir*. This appears to be one of the more rare *Mir* QSL cards.

Mir Crew Returns to Earth

News agencies around the world all reported the same story: for the first time in over ten years, there's nobody in space. Todd Halvorson of the newspaper *Florida Today* told ANS that "in an emotional overture to a fiery grand finale, an international crew left Russia's aging space station *Mir* early Saturday morning, reducing Earth's orbital population to zero." The crew's departure also signaled an end to Amateur Radio operation aboard the *Mir* station.

Mir had been occupied for 3,641 consecutive days. The departure followed a hectic two weeks in which the crew shut down station laboratories, filled up its garbage scow and switched off all but essential systems. A new crew, meanwhile, is being trained for a short mission that might be needed to make final preparations for what would amount to a burial-at-sea. The schedule calls for cosmonauts to fly to *Mir* in February or March of 2000 and to oversee the arrival of a fuel-filled Russian space freighter. The freighter would periodically fire onboard thrusters, nudging *Mir* into a lower orbit of about 125 to 135 miles above Earth. The crew then would abandon ship and return to Earth before the freighter gives *Mir* a powerful last push into the upper atmosphere.

Mir has placed some incredible numbers in the record books, starting with orbits. *Mir* orbits the Earth about 16 times a day, for total of more than 77,000 to date. The station has been aloft for almost 5,000 days going back to the core component launch and has seen nearly 100 passengers, including seven NASA astronauts, a Japanese journalist, a British candymaker and several other foreign visitors. *Mir* was also the setting for the longest stay in space by Cosmonaut Valery Polyakov (recording 438 days in 1994-95). Many of the visitors were ham operators who were very *radio-active* from the station during their stay.

Many satellite operators posted comments on the AMSAT-BB about *Mir*. Jeff, W4JEF, essentially captured the thoughts of many with his posting, "may the memory of the fun we've all had with *Mir* remained etched in our minds for years to come." (via AMSAT News Service)

Amateur Radio on the International Space Station Is One Step Closer

Will Marchant, KC6ROL has informed us that the first set of flight hardware for the Amateur Radio on the International Space Station (ARISS) project has passed all its tests and is on its way to Kennedy Space Center (KSC), Florida. After a tremendous amount of work by Frank Bauer, KA3HDO, and his team of volunteers at Goddard Space Flight Center, Maryland, the radios, TNC, power supplies, and harnesses for the initial transportable ARISS station are ready. The hardware was shipped to KSC on the 9 August 1999 where it will be loaded into the STS-101 SpaceHab module. Launch of mission STS-101 to the ISS is contingent upon successful launch of the Russian Service Module.

Initial ARISS will consist of voice and AFSK packet on both 2m and 70cm. Future upgrades will include more bands and modes. The ARISS external antennas, which were developed by the Italian ARISS team, will be mounted on the outside of the ISS Service module during a spacewalk scheduled during STS-101. Four external antennas will be flown to allow support of Amateur Radio communications in HF, VHF, UHF, L (including GPS receive) and S bands.

Additional photographs taken during testing are available at the ARISS WWW site at <http://gar4.gsfc.nasa.gov/~ka3zyx/ariss/ariss.html>

Vacationing at the Phase 3D Integration Laboratory

Steve Diggs, W4EPI and his family recently took a family vacation to Orlando, Florida. With the cooperation of his XYL, Steve was able to spend three days at the Phase 3D Lab, as they prepared to transport the spacecraft to Goddard Spaceflight Center, Maryland for spin and vibration testing. The following is Steve's report on his experience:

In case you didn't know it, the Phase 3D Team at the Lab is really working *hard* to get this spacecraft ready to fly *soon*. Whether it really does or not...well that's a different matter. But the bird will be ready to fly based on the effort I saw being put into it.

My first day was spent with Stan Wood, WA4NFY getting a solar *barrier*, for lack of a better word, ready to install over two of the parabolic antenna bases. The theory is that this substance prevents the sun's solar energy being focused onto the antenna elements and literally burning it to a crisp, yet is completely transparent to RF. My second day at the Lab started by finishing the installation. Afterwards, Stan had me give the machine shop a *thorough* cleaning. (Hey, I'm not proud; I'd do whatever needed to be done just to watch while the rest of the experts did the hard stuff). Everyone at the Lab was in a big crunch getting everything ready for the shake test. Most of the final work seemed to revolve around getting Phase 3D's solar panel mountings right.

Next, I went on one of those proverbial parts-hunting trips with Stan and Lou McFadin, W5DID. What an education! It turned out that the part we needed was stocked at a local hardware store, which was the fourth place we visited. Go figure! Anyway during this hunt, one of the discussion topics was the test plan for the shake test. I have experience with software and computer systems test plans, and offered to help in that area. The existing plan had all the right elements in it; the information just needed to be arranged in an industry standard (IEEE) format. By the end of day three, the test plan was ready to go, and so was the spacecraft.

I didn't get to make it back for a fourth day at the lab. But I'm sure that was the day the spacecraft got loaded on the truck and started on its long trip to Maryland for vibration testing.

I'd highly recommend that if you are in the Orlando area, to give Lou McFadin a call or e-mail post beforehand and offer your services. They may have you operating a vacuum cleaner most of the time, but it will be an experience you won't soon forget. 73, Steve Diggs, W4EPI, Atlanta, GA AMSAT Area Coordinator.

[Apogee View, Continued from page 3]

personal financial advisor before making your donation. These folks are in a much better position to understand and advise you on your own individual tax liability.

AMSAT-North America is the principal Amateur Radio organization supporting the development of skills and specialized knowledge in the art and practice of Amateur Radio space communications and science in space. That's a tall order. And, even though our labor pool is almost exclusively made up of volunteers, it still takes financial resources...lots of them....to procure the services and "things" those volunteers use to keep our organization running smoothly.

You can help us to continue this mission. Leaving AMSAT a legacy, large or small, in the form of a cash donation, life insurance policy, shares of stock or as part of your estate, will help us insure our organization remains fiscally solvent in the years ahead

Keith Baker, KB1SF

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Keeps things running cool and quiet

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Transmit: 2 Meter, 440 MHz (70 CM)
Receive: 136-174 MHz, 440-450 MHz
(guaranteed 144 - 148 and 440 - 450 MHz only)
Mode: SSB, CW, FM
Power: 2M SSB: 6-35W, continuous
2M CW, FM: 6-45W, continuous
440 MHz SSB: 6-30W, continuous
440 MHz CW, FM: 6-40W, continuous
Power Supply Requirement: ... 13.8 V DC
Memory Channels: 160 Total,
80 Channels Per Band
VHF Antenna Connector: ... SO-239 (50)
UHF Antenna Connector: ... Type-N (50)
Size: 9.5(W) x 3.7(H) x 9.4(D) in.
241(W) x 94(H) x 239(D) mm
Weight: 11.0 lb
5.0 kg

FEATURES

- **Continuously Adjustable TX Power**
 - More control
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- **Independent Main / Sub Band Rx**
 - Tuning, AF and squelch level, and 4 function control switches per band
 - In Satellite mode, Sub is uplink, Main is downlink
 - IF shift for either Main/Sub band
- **9600 or 1200 BPS Packet Capable**
 - Direct audio modulation
 - Excellent C/N ratio
 - Excellent frequency stability
 - Adjustable ACC modulation signal levels
- **High Frequency Stability**
 - ± 3 ppm standard; ± 0.5 ppm optional
- **100% Duty Cycle**
- **AF Speech Compressor** for increased average talk power
- **Auto Repeater** with one-touch repeater functions
 - Built-In RIT Function
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– QST Magazine, 3/97

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